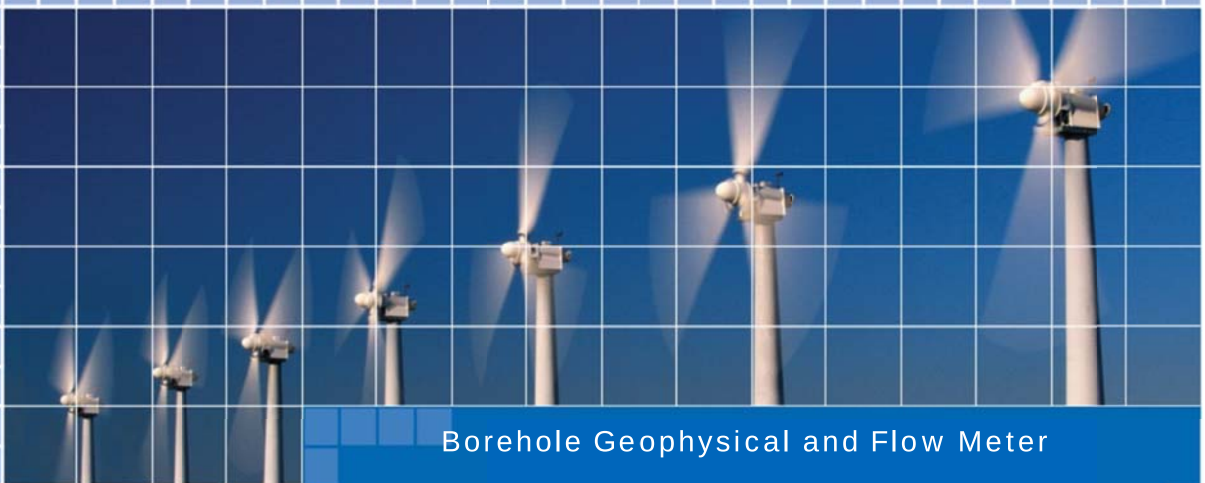

Borehole Geophysical and Flow Meter Logging Report - Upgradient Locations

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1 Introduction

WSP Environment and Energy (WSP) has prepared this report presenting the results of borehole geophysical and flow meter logging conducted at upgradient borehole locations A-14, A-15, and A-16 at the Nu-West Industries, Inc. (Nu-West) Conda Phosphate Operations (CPO) facility in Soda Springs, Idaho. The testing was performed by Colog, Inc. (Colog) under the direction of WSP in conformance with the scope of work described in the Work Plan for Additional Requirements dated July 11, 2011 (Work Plan) which was approved by the U.S. Environmental Protection Agency (EPA) on July 13, 2011. Colog's final report was received on October 5, 2011. The following sections include summaries of the borehole geophysical and flow meter logging procedures and results followed by a proposal for monitoring well screened intervals for these three locations.

1.1 SUMMARY OF DRILLING AND GEOPHYSICAL LOGGING SCOPE

The Work Plan proposed borehole geophysical and flow meter logging at five upgradient well locations, designated as A-13 through A-17 (Figure 1), oriented from south to north. Drilling observations at A-13 through A-17 were reported in a letter prepared by WSP dated August 29, 2011 (Drilling Summary) which was submitted to EPA. EPA responded to the Drilling Summary in a letter dated August 31, 2011. Findings from the Drilling Summary and EPA response letter for each borehole are summarized below:

- A-13 was characterized by presence of poorly consolidated conglomerate, unconsolidated gravel, sandstone and siltstone that varied from poorly to well consolidated. The A-13 borehole collapsed during drilling. Given observed drilling conditions, EPA agreed to forego geophysical logging at A-13 and instead, approved well installation with screened interval from 115 to 135 feet bgs. Monitoring well A-13 was installed between September 8 and 13, 2011.
- At A-14 and A-15, surface casing was installed from ground surface into the top of competent bedrock at depths of 58.5 and 54 feet below ground surface (bgs), respectively. A-14 is located approximately 20 feet north of A-15. A-14 was installed to a total depth 200 feet bgs, and basalt was identified between 56 and 145 feet bgs. The basalt is underlain by sedimentary sandstone and claystone. EPA approved installation of A-15 to a termination depth located at the basalt-sandstone contact, with the expectation that final construction of monitoring well A-14 would be screened in the underlying sedimentary aquifer, and monitoring well A-15 would be screened within the basalt aquifer. For A-14, the full geophysical logging suite was conducted in accordance with the Work Plan. For A-15, EPA approved a revised downhole geophysical logging suite (i.e., caliper, natural gamma, gamma-gamma-density, and neutron porosity) to provide confirmation of the lithologic observations at A-14 without unnecessary duplication of the full geophysical suite and flow meter testing.
- At A-16, surface casing was installed into the top of competent bedrock at 111 feet bgs. From 111 to 200 feet bgs, lithology consisted of interbedded claystone, siltstone, limestone, and minor sandstone with variable competency. For A-16, the full geological physical logging suite was conducted in accordance with the Work Plan.
- A-17 was characterized by presence of poorly consolidated material, consisting of fine-grained sandstone. Given the inability to maintain an open borehole for geophysical logging, EPA agreed to forego geophysical logging at A-17 and instead, approved well installation with screened interval from 130 to 150 feet bgs. Monitoring well A-17 was installed between August 30 and September 1, 2011.

For reference, lithologic logs for A-14 and A-16 are provided as Appendix A. In summary, geophysical logging was completed at the A-14 and A-15 paired boreholes, and at A-16. Results of geophysical logging at these three boreholes are described in this report.

2 Borehole Geophysical Logging Procedures

Geophysical logging of A-14, A-15, and A-16 was completed from September 8 through 10, 2011. Geophysical logging at A-14 and A-16 consisted of the following methods, shown in the order that they were conducted[1]:

- Optical Televiewer — provides a flattened 360-degree image of the borehole wall using optical digital camera. Optical televiewer images allow for assessment of fracture depth, spacing, aperture, and orientation and show the general appearance of the borehole wall, including rock color and healed fractures. Optical televiewer requires that the borehole fluid have very low turbidity. Optical televiewer logging was conducted using an Advanced Logic Technologies model OBI-40 optical televiewer.
- Fluid conductivity and fluid temperature—deflections and changes in the slope of the conductivity and temperature logs are potential indicators of where groundwater is entering or leaving the borehole. Fluid conductivity and temperature logging was conducted using a Mt. Sopris model QL-40 stackable CAL probe.
- Borehole diameter using 3-arm caliper—measures borehole diameter and identifies fractures. The 3arm caliper logging was conducted using a Mount Sopris model QL-40 stackable CAL probe.
- Natural gamma radiation (E-log)—identifies changes in lithology and is used to correlate stratigraphy between boreholes. Natural gamma radiation was logged on several tools, but the log presented for A-14 and A-16 was collected using a Mount Sopris model 2PGA/2PEA probe as part of the E-log suite.
- Spontaneous potential (E-log) — identifies changes lithology. Spontaneous potential logging requires a borehole fluid and was conducted using a Mount Sopris model 2PGA/2PEA probe as part of the E-log suite.
- Single-point resistance (E-log)—identifies changes in lithology, porosity, clay content, or total dissolved solids in the formation water. Single-point resistance logging requires a borehole fluid and was conducted using a Mt. Sopris model 2PGA/2PEA probe as part of the E-log suite.
- Normal resistivity (E-log)—identifies vertical changes in resistivity in the surrounding formation and can be correlated with surface resistivity measurements (e.g., ERI survey data). Normal resistivity logs include both the short normal [16 inch (16”)] and long normal [64 inch (64”)], which refers to the electrode spacing and changes the effective volume of formation being included in the resistivity measurement. Normal resistivity logging requires a borehole fluid and was conducted using a Mount Sopris model 2PGA/2PEA probe as part of the E-log suite.
- Full waveform sonic velocity – identifies seismic wave velocity in the surrounding formation and can be used to correlate the depth of seismic reflectors in surface seismic data. Sonic logging requires a borehole fluid and was conducted using a Mount Sopris model 2SAF-3 probe configured with three receivers at 3, 4, and 5 feet above the sonic transmitter.
- Gamma-gamma density (also called compensated density) – identifies vertical changes is surrounding formation bulk density and can be used to identify the basalt intraflow density changes and transitions between basalt flow and interflow lithologies. Gamma-gamma density logging does

[1] The electromagnetic induction tool, which measures formation electrical conductivity, was not available at the time of geophysical logging activities. The electromagnetic induction tool measures formation properties analogous to normal resistivity logging, which was conducted throughout the open bedrock portions of the A-14 and A-16 boreholes.

not require a borehole fluid and can be conducted through casing. The gamma-gamma density tool used during the logging (Robertson Geologging model FDGS) uses a Cesium-137 radioactive source.

- Neutron porosity – measures vertical changes in hydrogen content of the surrounding formation and can be used to determine porosity and identify basalt flow boundaries, interflow zones, and fracture zones. Neutron porosity logging does not require a borehole fluid, although neutron logging in unsaturated conditions is essentially measuring any moisture content in the formation. Neutron porosity logging can be conducted through casing. The neutron porosity tool used during logging (Robertson Geologging model DNNS) uses an Americium-241-Beryllium radioactive source and detects neutron flux in the thermal range (<0.1 eV).

Geophysical logging at A-15 consisted of the following methods:

- Fluid conductivity and fluid temperature
- Borehole diameter using 3-arm caliper
- Natural gamma radiation (logged on density and neutron probes)
- Gamma-gamma density
- Neutron porosity

With the exception of fluid conductivity, geophysical logging tools are calibrated by the manufacturer and undergo period calibration checks prior to usage. The fluid conductivity probe is periodically calibrated using standard solutions. Equipment specifications are provided in Colog’s final report (Appendix B).

All geophysical logging was conducted relative to the top of steel surface casing (i.e. zero depth is top of casing and not ground surface). All depths reported here are in feet below top of casing (btoc). The height of the surface casing stick-up relative to ground surface is 1.5 feet at A-14, 1.7 feet at A-15, and 1.3 feet at A-16.

Features indicating potential groundwater inflow and outflow (e.g., discrete fractures, fracture or rubble zones, lithologic transitions, and fluid temperature and conductivity changes) identified during geophysical logging were targeted for flow meter testing.

3 Borehole Geophysical Logging Results

Colog's final report is included in Appendix B and includes a summary of the methodology, results, interpretations, and includes Geophysical/Hydrophysical Summary Plots for each borehole that combine the results for selected logs most useful in the interpretation. Results of all geophysical logs are provided in Colog's geophysical survey results in Appendix B.

A description of geophysical logging results is provided in this section.

3.1 A-14 AND A-15

Prior to geophysical logging, depth to water was measured at A-14 (54.28 feet btoc) and A-15 (54.34 feet btoc).

3.1.1 Optical Televiewer and Caliper Log

The borehole wall image derived from the optical televiewer is paired with the caliper log in the Optical Televiewer Image Plot (Appendix B). The Optical Televiewer Image Plot also includes the sinusoidal projections and tadpole points demonstrating the orientation of planar features identified in the optical televiewer image. The high resolution of the optical televiewer image allows for a detailed assessment of the basalt and underlying sedimentary rocks. Within the basalt portion of the log (60.8 to 146.5 feet btoc), the individual basalt flow sequence is evident with flow tops characterized by increased fracturing, discoloration, and larger and closer spaced vesicles. The dense flow interiors are largely unfractured with very few, smaller vesicles. The visually identified fractures associated with the flow tops coincide with increased borehole diameter (i.e., diameter greater than 6-inches) as measured by the 3-arm caliper.

The basalt at A-14 is underlain by a sedimentary sequence dominated by sandstone and claystone. Within this portion of the borehole (146.5 to 202.6 feet btoc), the optical televiewer indicates the orientation and thickness of bedding and images bedding-plane parallel and vertical fractures. A prominent vertical fracture occurs from 156 to 180 feet btoc.

The basalt-sedimentary contact at 146.5 to 149.2 feet btoc is characterized by a borehole diameter increase reaching 10.5 inches at 149 feet btoc. The optical televiewer image at the lithologic contact indicates a significant open fracture at 147.0 to 147.2 feet btoc and what appears to be gravel from 148 to 149.2 feet btoc.

The basalt at A-14 is underlain by a sedimentary sequence dominated by sandstone and claystone. Within this portion of the borehole (146.5 to 202.6 feet btoc), the optical televiewer indicates the orientation and thickness of bedding and images bedding-plane parallel and vertical fractures. A prominent vertical fracture occurs from 156 to 180 feet btoc. The Colog report includes a Schmidt equal area stereonet plot of the poles to planar features in the A-14 borehole. The poles to sedimentary bedding define a center of concentration in the stereonet data that corresponds to an average strike of 327° dipping 38° to the northwest. This orientation of bedding is consistent with the orientation of bedding in exposed outcrop in the Aspen Range approximately 1,000 feet to the east.

3.1.2 Fluid Temperature and Conductivity Log

The A-14 fluid temperature and conductivity logs indicate that the borehole fluid is changing between approximately 90 and 100 feet btoc and between 190 and 195 feet btoc, suggesting presence of groundwater inflow or outflow zones within the borehole. Between 80 and 100 feet btoc, the fluid conductivity increases from approximately 1,000 to 1,900 µS/cm, and fluid temperature decreases at 97 feet btoc.

3.1.3 Natural Gamma Log

Natural gamma logs are sensitive to increasing clay content in the formation, and for basalt, natural gamma is useful for identifying clay interbeds within the sequence, if present. The natural gamma counts per second (cps) in the A-14 log are relatively low within the basalt (less than 60 cps) but increase to approximately 180 to 240 cps at the bottom of the borehole between 160 and 200 feet btoc in the sedimentary rocks and reflect the higher clay content of the sedimentary rocks.

3.1.4 Single Point Resistance Log

The single-point resistance (SPR) log for A-14 exhibits oscillations with lower resistance of approximately 100 ohms associated with fractured basalt flow tops and discrete fractures within the basalt sequence (e.g. 105 feet btoc) and higher resistance of approximately 200 ohms associated with the dense, basalt flow interiors. Within the underlying sedimentary rocks, the SPR log is relatively constant within the approximate range of 50 to 70 ohms.

3.1.5 Normal Resistivity Log

Normal resistivity logs measure the formation resistivity using a downhole electrode array and are sensitive to changing resistivity due to changing lithology or formation water content and conductivity. In basalt, normal resistivity logs are useful in differentiating between the resistive flow interiors and the more conductive interflow zones with associated higher porosity and clay content. In the A-14 logs, the long normal resistivity log (64”) correlates well with the other geophysical and televiewer logs, exhibiting increased resistivity in the basalt flow interiors and decreased resistivity in the flow boundaries. The short normal resistivity log (16”) exhibits the same general pattern as the long normal resistivity log, however, the logs may exhibit resistivity reversals [where the long and short normal resistivity logs diverge due to lithologic contrasts thinner than the 64” electrode spacing but thicker than the 16” electrode spacing; Helm-Clark et al (1994)] in the depth range of 65 to 80 feet btoc. The underlying sandstone and claystone exhibit an overall lower and less variable resistivity than the basalt.

3.1.6 Full Waveform Sonic Velocity Log

The full waveform sonic velocity log for A-14 exhibits variability in P-wave and S-wave velocity within the basalt that correlates to the fractured basalt flow tops and dense flow interiors. Lower P-wave velocity of approximately 10,000 feet per second (ft/s) was measured at depths corresponding to basalt flow tops (i.e. 61, 73, 80, and 90 feet btoc), while higher P-wave velocity of approximately 12,000 to 18,000 ft/s was measured at depths corresponding to basalt flow interiors. The S-wave velocity exhibits a similar pattern, but the velocity variation is less pronounced. Within the underlying sedimentary rocks, the P-wave velocity decreases to approximately 6,000 to 8,000 ft/s. The sedimentary rocks exhibit a “slow formation” response, and the S-wave velocity cannot be determined as the seismic velocity of the borehole fluid is greater than the S-wave velocity of the formation and precedes the shear head wave arrival at the detectors. The sonic velocity logs also include the P-wave and S-wave slowness, which is an inverse of the velocity.

3.1.7 Gamma-Gamma Density Log

Gamma-gamma-density logs, reported as “Short Spaced Density” and “Long Spaced Density” on Colog’s report, reflect the density of the formation or presence of void space, and for basalt are useful for identifying the variation between the dense flow interiors and lower density flow tops and interflow zones. In the A-14 density logs, numerous low density deflections occur between 60 and 104 feet btoc and correlate to basalt flow boundaries and fractures identified in the optical televiewer log. The underlying sandstone and claystone exhibit an overall lower and more variable density than the basalt and do not exhibit the prominent sharp density deflections associated with the basalt flow boundaries.

3.1.8 Neutron Porosity Log

Neutron porosity logs, reported as “Near Neutron” and “Far Neutron” on Colog’s report, measure of water content of the formation, with increasing counts per second (cps) associated with decreased bulk porosity, which, in a saturated zone, indicates a decrease in water content. For basalt, the neutron logs are useful for identifying the increased porosity associated with saturated interflow zones or the presence of hydrous alteration minerals. In the A-14 neutron logs, there is a shift toward lower neutron cps at the water surface (54.3 feet btoc) and deflections toward lower neutron cps associated with the fractured basalt interflow zones (e.g. 72 to 73 feet btoc and 88 to 95 feet btoc). The neutron logs show little variation in the underlying sedimentary rocks.

3.1.9 Summary

The results of limited geophysical logging suite at A-15 are plotted against results from A-14 on Figure 2. As shown on Figure 2, the geophysical logging results at A-14 and A-15 are very similar. The only noteworthy differences between the A-14 and A-15 logs are associated with discrete fractures observed in the A-14 log at 62, 67, 100.5, and 104 to 106 feet btoc that were not observed in the A-15 logs. The A-15 logs do indicate a fracture at 130 feet btoc that was not evident in the A-14 logs. The basalt interflow zones, however, are evident in the A-15 logs and correlate to the same depths in the A-14 logs (i.e. 72, 80, and 89 feet btoc). Overall, the A-15 logs correlate well with the A-14 logs and indicate that the screened interval for A-15 can, in part, be based upon geophysical and flow meter logging results from A-14.

The suite of geophysical logs at A-14 was used to identify the basalt flow sequence according to the methodology of Helm-Clark et al. (1994). The interpreted basalt flows occur at:

- 60.8 to 72.6 feet btoc (11.8 feet thick)
- 72.6 to 79.8 feet btoc (7.2 feet thick)
- 79.8 to 88.4 feet btoc (8.6 feet thick)
- 88.4 to 146.5 feet btoc (58.1 feet thick)

The suite of geophysical logs produced at A-14 and A-15 were also used identify specific features that warranted investigation as a part of the flow meter testing. In the A-14 borehole, eight features were identified:

- Basalt flow top at 72 to 73 feet btoc
- Basalt flow top at 79.8 feet btoc
- Basalt flow top at 88 to 95 feet btoc
- Discrete fractures at 100 to 100.6 feet btoc and 104 to 106 feet btoc
- Dense, basalt flow interior at 106 to 146.4 feet btoc
- Basalt-sedimentary contact at 146.4 to 149.2 feet btoc
- Zone of borehole enlargement within sedimentary rocks at 160 to 185 feet btoc
- Zone of fluid temperature / conductivity deflection within the sedimentary rocks at 191 to 192 feet btoc

These eight features were targeted for flow meter testing as described in Section 4.

3.2 A-16

The bedrock portion of the A-16 borehole did not encounter basalt and was advanced entirely within the sedimentary section. The observed lithology during rock coring consisted of an interbedded sequence of sandstone, siltstone, claystone, and limestone (Appendix A). Prior to geophysical logging, depth to water was measured at 100.42 Feet btoc.

3.2.1 Optical Televiewer and 3-Arm Caliper Log

The optical televiewer log for A-16 confirms the variable interbedded lithologies observed in the A-16 rock core and indicates a northeasterly dip direction on the sedimentary bedding. The most prominent features in the optical televiewer log are changes in rock color associated with the sedimentary bedding and a few poorly defined high-angle fractures that intercept the borehole and exhibit a characteristic sinusoidal shape in the televiewer image (e.g. 134 to 138.4 feet btoc). The Colog report includes a Schmidt equal area stereonet plot of the poles to planar features in the A-16 borehole. The poles to sedimentary bedding define a center of concentration in the stereonet data that corresponds to an average strike of 325° dipping 42° to the northwest. This orientation of bedding is consistent with the orientation of bedding in exposed outcrop in the Aspen Range to the east.

The 3-arm caliper log for A-16 indicates several zones of borehole enlargement associated with stratigraphic intervals or discrete fractures:

- 128 to 129.4 feet btoc – stratigrahic interval
- 132.6 to 134 feet btoc – stratigrahic interval
- 140 to 141 feet btoc – discrete fracture
- 145.6 to 147 feet btoc – stratigrahic interval
- 149.4 to 151 feet btoc – stratigrahic interval
- 174 to 186 feet btoc. – stratigrahic interval

3.2.2 Fluid and Conductivity Logs

The fluid temperature and conductivity logs are constant from the bottom of the surface casing (113.8 feet btoc) to bottom of the borehole (201.5 feet btoc) and suggest that there are no prominent zones of groundwater inflow or outflow in the borehole.

3.2.3 Natural Gamma Log

The natural gamma log for A-16 exhibits some variability with higher cps associated with stratigraphic intervals from approximately 125 to 150 feet btoc and from approximately 169 to 188 feet btoc that consisted of sandstone, siltstone, and claystone. Lower natural gamma in the interval from 150 to 169 feet btoc corresponds to limestone identified in the rock cores.

3.2.4 Single Point Resistance Log

The SPR log for A-16 exhibits deflections with higher resistance centered at several depths associated with lithologic changes observed in the rock cores and optical televiewer log (e.g. 128, 132, 162, and 180 feet btoc).

3.2.5 Normal Resistivity Log

The normal resistivity logs for A-16 exhibit minimal variation with depth, oscillating between 0 and 200 ohm-meters from approximately 125 to 200 feet btoc. A zone of increased resistivity is apparent in the long normal resistivity log from approximately 119 to 124 feet btoc but does not appear to correlate with deflections on other geophysical logs.

3.2.6 Full Waveform Sonic Velocity Log

The full waveform sonic velocity log for A-16 exhibits a pattern similar to the sedimentary portion of the A-14 borehole, with measured P-wave velocity of approximately 6,000 to 8,000 ft/s and no quantifiable S-wave velocity.

3.2.7 Gamma-Gamma Density Log

The gamma-gamma-density logs for A-16 exhibit some variation with depth, with the most prominent deflections to lower density associated with borehole diameter increases and lithologic changes observed in the rock cores and optical televiewer log (e.g. 127, 132, and 149 feet btoc). The density logs indicate relatively constant and slightly higher density associated with limestone between 150 and 170 feet btoc.

3.2.8 Neutron Log

The neutron logs for A-16 exhibit minimal variation with depth and suggest generally consistent bulk porosity with depth.

3.2.9 Summary

Unlike the geophysical logs generated within the basalt at A-14, the suite of geophysical logs generated at A-16 indicates relatively minor variability with depth in the borehole. The sedimentary sections of both A-14 and A-16 lack the prominent zones of potential groundwater inflow and outflow identified in the basalt. The suite of geophysical logs produced at A-16 were also used identify specific features that warranted investigation as a part of the flow meter testing. A total of six features were identified:

- Stratigraphic interval with borehole diameter increase at 128-129.4 feet btoc
- Stratigraphic interval with borehole diameter increase at 132.6 -134 feet btoc
- Discrete fractures at 138-141 feet btoc
- Stratigraphic interval with borehole diameter increase at 145-147 feet btoc
- Stratigraphic interval with borehole diameter increase at 149-151 feet btoc
- Stratigraphic interval with borehole diameter increase at 174-186 feet btoc

4 Flow Meter Logging Procedures

4.1 FEATURES TARGETED FOR FLOW METER TESTING

The geophysical logging results were used to select intervals for flow meter logging in A-14 and A-16. Intervals were selected by identifying specific fractures, fracture zones, lithologic transitions, or fluid temperature and conductivity changes that might indicate locations where groundwater flow is entering or leaving the borehole. Additional intervals where no indications of groundwater flow were occurring based on geophysical logging were included for completeness.

Flow meter testing was conducted at A-14 and A-16 under both ambient and stressed (pumping) conditions. Ambient flow meter testing was performed to measure the direction and the magnitude of vertical flow and the stressed conditions test was intended to reverse flow in all zones of outflow such that these intervals become zones of inflow during pumping. The resulting flow profile is used to estimate the transmissivity of each zone of flow where flow is reversed during the stressed test. In cases where significant drawdown is achieved during pumping, the stress test can also induce flow in relatively transmissive zones that may not produce flow under ambient conditions. Summary of ambient and stressed testing results is provided in Colog’s final report.

4.1.1 Zones for Flow Meter Testing in A-14

In A-14, flow meter was conducted in the saturated portion of the borehole, from 60.8 feet btoc (bottom of surface casing) to 202.7 feet btoc (bottom of borehole).

At A-14, 12 flow meter logging intervals were selected to evaluate vertical borehole flow associated with eight identified features.

- 69 feet btoc – above fracture at 72-73 feet btoc
- 76.5 feet btoc – between fractures at 72-73 and 79.8 feet btoc
- 86 feet btoc – between fracture at 79.8 feet btoc and fracture zone at 88-95 feet btoc
- 96 feet btoc – between fracture zone at 88-95 feet btoc and fracture at 100 to 100.6 feet btoc
- 116 feet btoc – below fracture zone at 104-106 feet btoc
- 133.3 feet btoc – middle of dense, lower basalt flow
- 145 feet btoc – above base of basalt at 146.4 feet btoc
- 151.5 feet btoc – below basalt-sedimentary contact at 146.4-149.2 feet btoc
- 186.6 feet btoc – below zone of borehole enlargement at 160-185 feet btoc
- 194 feet btoc – below zone of fluid temperature / conductivity deflection at 191-192 feet btoc
- 200 feet btoc – bottom of borehole

4.1.2 Zones for Flow Meter Testing in A-16

In A-16, flow meter logging was conducted in the saturated portion of the borehole, from 113.8 feet btoc (bottom of surface casing) to 200.5 feet btoc (bottom of borehole).

At A-16, seven flow meter logging intervals were initially selected to evaluate vertical borehole flow associated with six identified features. Three additional intervals were added during the stressed test to provide better refinement of flow in the borehole.

- 116 feet btoc – shallow interval below bottom of surface casing

- 131 feet btoc – below thin bed with borehole diameter increase at 128-129.5 feet btoc
- 136 feet btoc – below thin bed with borehole diameter increase at 132-134 feet btoc
- 143 feet btoc – below fractures at 138-141 feet btoc
- 148 feet btoc – below thin bed with borehole diameter increase at 145-147 feet btoc
- 156 feet btoc – below thin bed with borehole diameter increase at 149-151 feet btoc
- 172 feet btoc – added during stressed test to refine upward flow
- 177.5 feet btoc – added during stressed test to refine upward flow
- 188 feet btoc – added during stressed test to refine upward flow
- 192 feet btoc – bottom of borehole

4.2 EQUIPMENT FOR FLOW METER TESTING

Flow meter testing was conducted using a Mount Sopris heat pulse flow meter (HPF; model number 4293) in conjunction the Mount Sopris Matrix logging computer. The HPF was factory-calibrated by the manufacturer to measure flow ranging between 0.03 and 1 gallon per minute (gpm; see calibration data in Appendix). This is the calibration range of the instrument; however, its practical measurement range (response that is outside the linear calibrated range of the instrument) is between 0.01 and 1.2 gpm. During field activities, flow rates were noted outside the calibrated and measurement range of the instrument. In such cases, results are reported as measured, but interpretation based on these values is less well constrained.

In addition to the HPF, flow meter testing at A-14 also utilized a Robertson Geologging impeller flow meter (also referred to as a spinner flow meter; model number HRFM) due to the higher pumping rates required to effectively stress the aquifer, which would be outside the measurement range of both the HPF and the electromagnetic flow meter. The impeller flowmeter has a higher measurement range than either the HPF or electromagnetic flow meters and is more accurate at higher velocities, but is limited to velocities greater than approximately 7 feet per minute (10 gpm in a 6-inch diameter borehole), at which point the impeller stalls. As a result, impeller flow meter measurements are also collected during constant-rate trolling of the flow meter through the borehole. The impeller flow meter records revolutions per minute (rpm) of the impeller blades. The rpm measurement is converted into gpm by assuming that the measured rpm at the top of the borehole correlates to the pumping rate and that the measured rpm at the bottom of the borehole correlates to no flow. The interval-specific change in measured rpm with depth in the borehole, as a percentage of the total change in rpm for the entire length of the borehole, is used to identify intervals of inflow during pumping and quantify the discharge of each interval.

4.2.1 Flow Meter Testing under Stressed Conditions

Pumping during the stressed test was conducted using, a 3-inch diameter Grundfos stainless-steel submersible pump (model number SQE 10-130). The specifications and pump curve for the Grundfos pump is provided in Appendix B**Error! Reference source not found.**. During stressed testing, the pump was maintained in a stationary position, while the flow meter, which was placed below the pump, was lowered through the borehole for flow measurements.

Before conducting the stressed test, the appropriate pumping rate was determined for each borehole with a short duration drawdown test. The goal of the drawdown test was to identify a pumping rate that would produce a stable drawdown of several feet, keeping the water level above the pump intake and within the surface casing. Observed pumping rates were measured with an inline flow meter and drawdown was measured with a pressure transducer deployed below the pump intake.

Based on drilling observations during borehole reaming, the anticipated yield at A-14 was high enough that the pump was operated at the highest pumping rate attainable (26.5 gpm) which resulted in a stable drawdown of 1.05 feet. At A-14, the pre-testing 26.5 gpm drawdown curve was used to estimate total borehole transmissivity.

By comparison, drilling observations at A-16 indicated that a significantly lower yield would be likely, so the pumping rate was decreased with an inline valve to 2.5 gpm, which resulted in a stable drawdown of 4.27 feet. After the completion of stressed testing at A-16, the pump was shut off and water level monitored until it had returned to the pre-test static water level. The recovery curve data at A-16 were used to estimate total borehole transmissivity.

At A-16, stressed test flow meter measurements were collected using HPF at each station where ambient test flow meter measurements were collected. At A-14, stressed test flow meter measurements were collected using either impeller or HPF at each station were ambient test flow meter measurements were collected, dependent on the measured velocity relative to the flow meter measurement range. Stationary measurements with the impeller flow meter, however, were irregular and were not used in the analysis. Instead, trolling profiles were collected with the impeller flow meter using different trolling speeds (13, 30, 60, and 90 feet per minute).

5 Flow Meter Logging Results

The results of the flow meter logging activities are provided in Colog's final report which is included as Appendix B and are summarized in Figures 3 and 4. Colog's report contains both HPF and impeller log that show the ambient and stressed testing results for each borehole. The results are logged as discrete measurements of flow at the selected intervals, with measured flow rates reported in gallons per minute (gpm). Positive flow measurements indicate upward flow and negative values indicate downward flow. Abrupt increases or decreases in vertical flow rates between measurement stations indicate potential zones of groundwater inflow or outflow. The impeller flow meter results for A-14 are presented in the Colog report as interval-specific inflow during the stressed test. In Figure 3, the interval-specific inflow rates have been added to approximate total upward flow during pumping.

The flow rates measured during testing were converted to flows into and out of the well by calculating the differences in measured flow rates between the flow meter stations. The data were interpreted in accordance with the guidelines for interpreting vertical flow data described in Molz et al. (1994) and Young et al. (1998) using the Flow-Log Analysis of Single Holes (FLASH) software program developed by Day-Lewis et al. (2011). The best fit model to the measured flow meter data indicated the same zones of inflow and outflow to the borehole as presented in Figures 3 and 4.

5.1 A-14

During ambient testing, upward flow of 0.045 gpm was measured at 86 feet btoc; and downward flow ranging from -0.105 to -0.800 gpm was measured from 96 to 151.5 feet btoc. Figure 3 includes the ambient and stressed test flow measurements and the interpreted zones of inflow and outflow. Four zones of inflow or outflow were identified during the ambient test:

- 79.8 feet btoc: minor outflow at basalt flow top constrained by flow meter measurements at 76.5 feet btoc (no flow) and 86 feet btoc (0.045 gpm upward).
- 88 to 106 feet btoc: inflow at basalt flow top (88 to 95 feet btoc) and discrete fractures (100-100.6 and 104-106 feet btoc) constrained by flow meter measurements at 86 feet btoc (0.045 gpm upward) and 116 feet btoc (0.800 gpm downward).
- 146.4 to 149.2 feet btoc: outflow at basalt-sedimentary contact constrained by flow meter measurements at 145 feet btoc (0.800 gpm downward) and 151.5 feet btoc (0.105 gpm downward)
- 160 to 185 feet btoc: outflow within sedimentary rocks constrained by flow meter measurements at 151.5 feet btoc (0.105 gpm downward) and 186.6 feet btoc (no flow).

During the stress test with the pump set at 58 feet btoc (below the static water level of 54.28 feet btoc) and a pumping rate of 26.4 gpm, flow was measured in the upward direction throughout the entire water column. Flow measurements during stress testing ranged from +0.01 to +26.4 gpm. The zones of inflow identified during the ambient test were responsible for the majority of inflow identified during the stressed test (i.e. 88 to 106 feet btoc). Flow meter measurements above 116 feet btoc were derived from the impeller flow meter data collected during trolling at 60 feet per minute. Flow meter measurements from 116 feet btoc to the bottom of the borehole were conducted with a HPF due to the low flow velocities. Less than 1 gpm was produced by the bottom of the borehole in the sedimentary rocks.

Due to the pump placement depth (i.e. several feet below static water level), trolling runs using the impeller flow meter were constrained to depths below which a constant trolling velocity could be attained (approximately 71 feet btoc). As a result, any potential inflow above this zone is not constrained by the stressed flow meter analysis.

5.2 A-16

During ambient testing, downward flow ranging from -0.010 to -0.024 gpm was measured from 136 to 156 feet btoc. Figure 4 includes the ambient and stressed test flow measurements and the interpreted zones of inflow and outflow. Two flow zones were identified in the ambient test:

- 127 to 147 feet btoc: minor inflow constrained by flow meter measurements at 116 feet btoc (no flow) and 147.8 feet btoc (0.022 gpm downward)
- 175 to 189 feet btoc: minor outflow constrained by flow meter measurements at 156 feet btoc (0.024 gpm downward) and 192 feet btoc (no flow).

During the stressed test, the pump intake was set at 113 feet btoc (below the static water level of 100.42 feet btoc). As a result of the pump placement at A-16, the shallowest flow meter interval during the stressed test was lowered from 116 to 118 feet btoc to avoid the pump. Stressed flow meter testing at A-16 was conducted at a pumping rate of 2.5 gpm, and flow was measured in the upward direction through the entire water column. Flow measurements during stress testing ranged from +0.262 to +1.356 gpm. The flow zones contributing the majority of inflow during the stressed test were:

- 177.5 to 188 feet btoc (0.56 gpm)
- 147.8 to 156 feet btoc (0.22 gpm).

6 Proposed Monitoring Well Screened Intervals

Based on an evaluation of the geophysical and flow meter logging results, this section presents proposed screened intervals for monitoring wells at A-14, A-15, and A-16.

6.1 A-14

The proposed screened interval for A-14 is from 160 to 180 feet btoc (158.5 to 178.5 feet bgs). This interval will provide a monitoring point for evaluating groundwater chemistry and potentiometric surface elevation for the underlying sedimentary sequence. The interval 160 to 180 feet btoc is a zone of fine-grained, thinly laminated sandstone with poor core recovery during drilling. The optical televiewer log for this interval indicates consistent lithology and the existence of a prominent vertical fracture from 156 to 180 feet btoc. The caliper log indicates borehole enlargement for this interval.

6.2 A-15

The proposed screened interval for A-15 is from 85 to 105 feet btoc (83.3 to 103.3 feet bgs). This interval will provide a monitoring point for evaluating groundwater chemistry and potentiometric surface elevation in the basalt sequence. The interval 85 to 105 feet btoc includes a recognized basalt flow top (88 to 95 feet btoc at A-14) that was identified as a significant inflow zone during ambient and stressed flow meter testing.

6.3 A-16

The proposed screened interval for A-16 is from 170 to 190 feet btoc (168.7 to 188.7 feet bgs). This interval will screen an interbedded sandstone and claystone sequence that was responsible for a significant amount of the observed inflow during the stressed flow meter test and outflow during the ambient flow meter test. The zone is associated with slight borehole diameter increase.

7 References

Day-Lewis, F.D., Johnson, C.D., Paillet, F.L., and Halford, K.J. 2011. A Computer Program for Flow-Log Analysis of Single Holes (FLASH). Groundwater.Domenico, P.A. and Schwartz, F.W., 1998. Physical and Chemical Hydrogeology, Second Edition.

Helm-Clark, C.M., Rodgers, D.W., and Smith, R.P. 2004. Borehole geophysical techniques to define stratigraphy, alteration and aquifers in basalt. Journal of Applied Geophysics, v55, p 3-38.

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Molz, F.J., Boman, G.K., Young, S.C., and Waldrop, W.R. 1994. Borehole Flow meters: Field Application and Data Analysis. Journal of Hydrology.

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Figures

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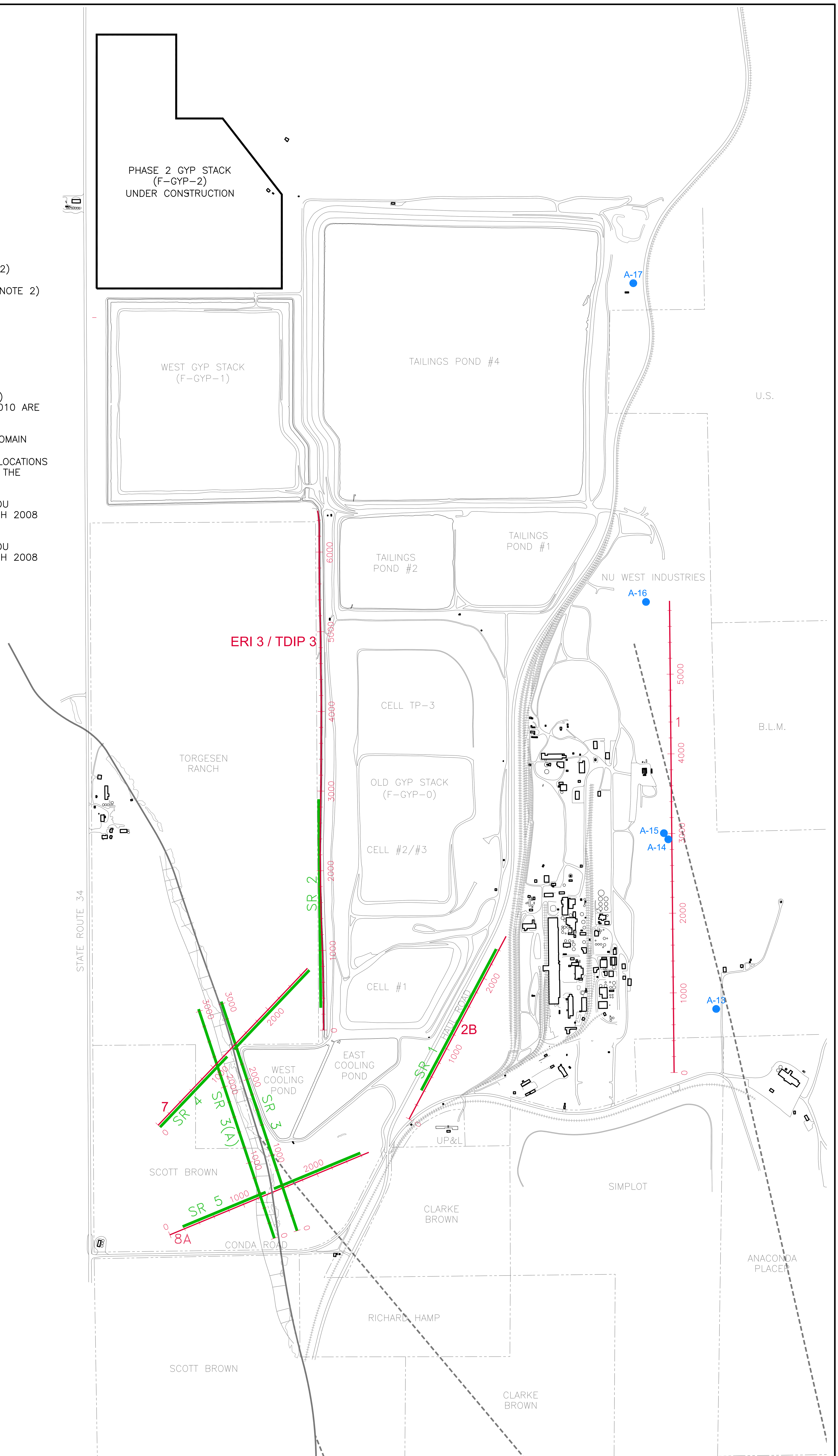
LEGEND

- A-13 ● UPGRADIENT MONITORING WELL
- COVERED FAULT
- TOPOGRAPHICAL DEPRESSION FAULT (WITH ROCK OUTCROP)
- ERI & TDIP TRANSECT (2010& 2011; SEE NOTE 1 & 2)
- PROPOSED SR TRANSECT (SEE NOTE 2)

NOTE:

1. SELECT ELECTRICAL RESISTIVITY IMAGING (ERI) TRANSECT LINES THAT WERE SURVEYED IN 2010 ARE SHOWN ON THIS FIGURE.
2. TRANSECTS PROPOSED FOR ERI AND TIME DOMAIN INDUCED POLARIZATION SURVEY AND SEISMIC REFLECTION (SR) SURVEY ARE SHOWN. THE LOCATIONS OF THESE TRANSECTS ARE CONSISTENT WITH THE LOCATIONS REQUESTED BY THE EPA.
3. PROPERTY LINES ARE APPROXIMATE. CARIBOU COUNTY ASSESSOR MAP OF T8S R42E, MARCH 2008 AND AVAILABLE INFORMATION.
4. PROPERTY LINES ARE APPROXIMATE. CARIBOU COUNTY ASSESSOR MAP OF T8S R42E, MARCH 2008 AND AVAILABLE INFORMATION.



0 600 1200 1800
SCALE IN FEET

REFERENCES:
1. MAP I-557 GEOLOGIC MAP OF THE SODA SPRINGS QUADRANGLE, SOUTHEASTERN IDAHO. USGS, 1969.
2. ECOLOGICAL RISK ASSESSMENT, NU-WEST CONDA FACILITY. ENERCON SERVICES, INC., APRIL 2008.
3. GROUNDWATER ASSESSMENT DATA, FALL 2008. ENGINEERS INC. MARCH 2009

Drawing Number 00023229-D03

FIGURE 1

WSP
WSP Environment & Energy, LLC
4600 South Ulster Street, Suite 930
Denver, Colorado 80237
(303) 850-9200
www.wspenvironmental.com/usa

UPGRADIENT MONITORING WELL LOCATIONS

NU-WEST CPO FACILITY
SODA SPRINGS, IDAHO

PREPARED FOR
HUNTON & WILLIAMS

DRAWN BY	RAZ 09272011
CHECKED	
APPROVED	

SEAL

DATE

REVISIONS

REV	DESCRIPTION		
1	Revised:	Chkd:	Appr.:
2	Revised:	Chkd:	Appr.:
3	Revised:	Chkd:	Appr.:

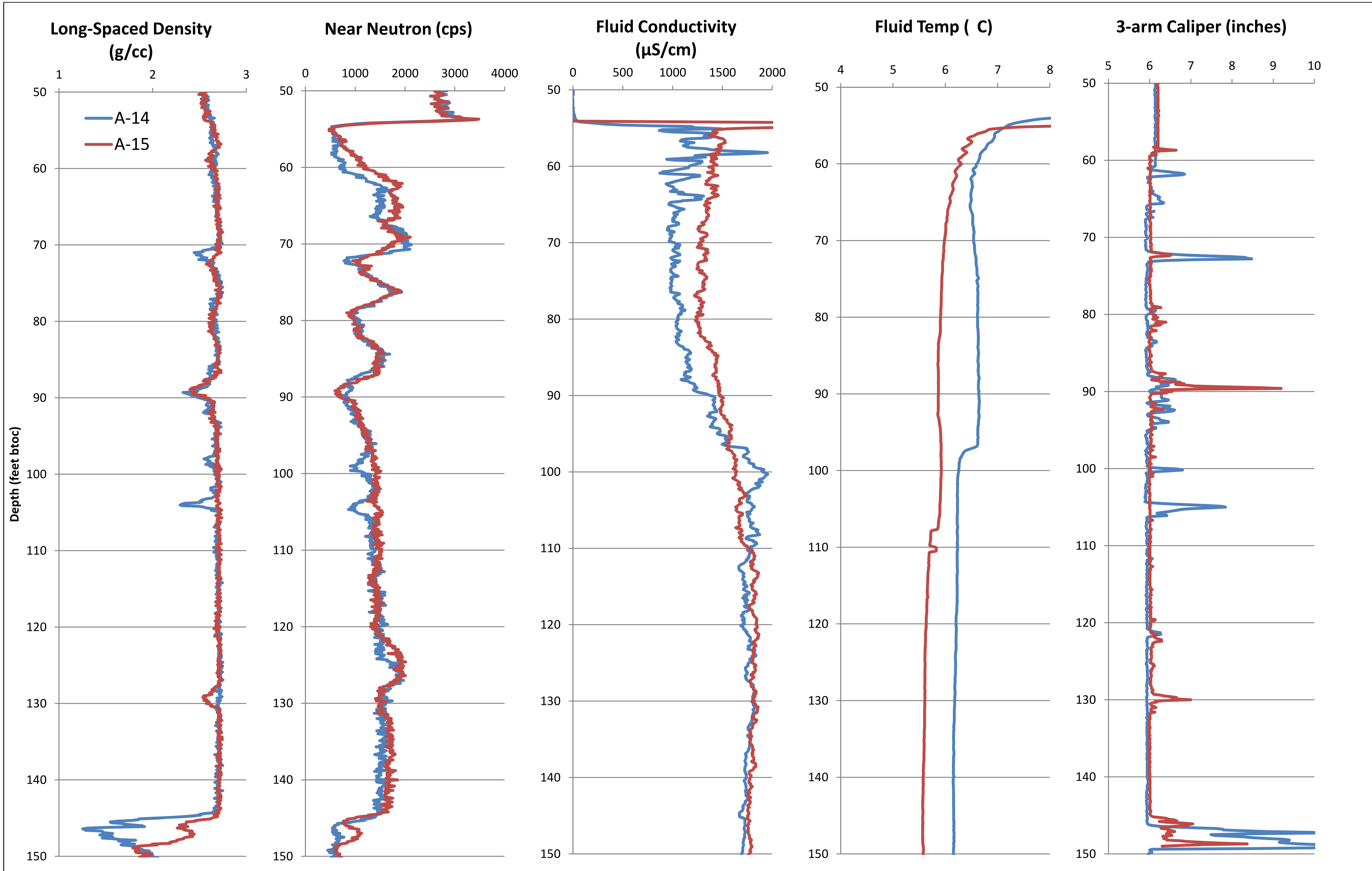


Figure 2
Comparison of A-14 and A-15 Geophysical Logs
Nu-West Industries, Inc.
Conda Phosphate Operations
Soda Springs, Idaho

4600 South Ulster Street, Suite 930
Denver, Colorado 80237
303-850-9200

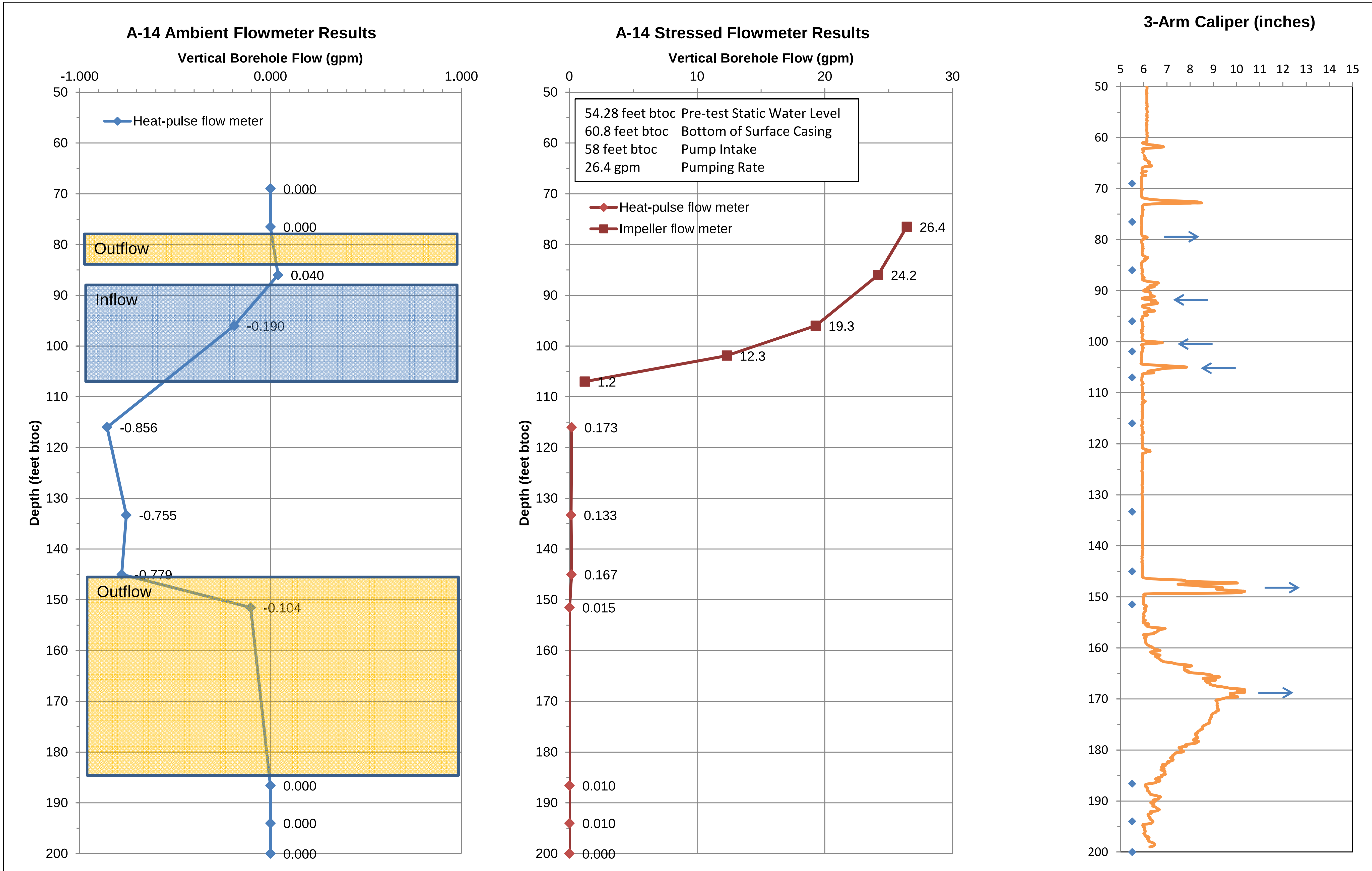


Figure 3
Summary of Flow Meter Testing Results - A-14
Nu-West Industries, Inc.
Conda Phospahte Operations
Soda Springs, Idaho

4600 South Ulster Street, Suite 930
Denver, Colorado 80237
303-850-9200

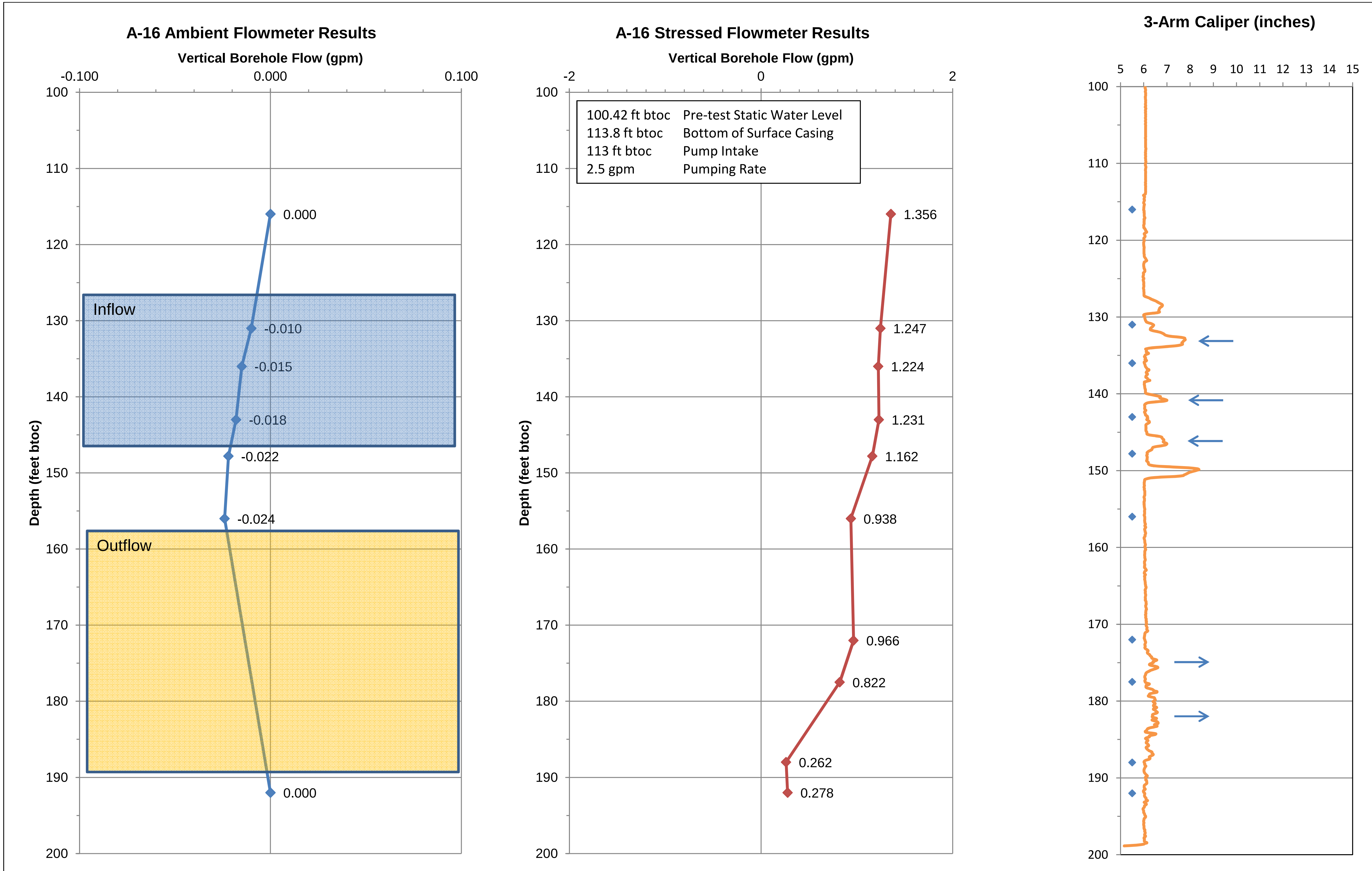


Figure 4
Summary of Flow Meter Testing Results - A-16
Nu-West Industries, Inc.
Conda Phospahte Operations
Soda Springs, Idaho

4600 South Ulster Street, Suite 930
Denver, Colorado 80237
303-850-9200

Appendix A – Lithologic Boring Logs for A-14 and A-16

Boring Log: A-14

Project: Agrium NuWest CPO
Project No.: 23229
Location: Soda Springs, ID
Completion Date: August 9, 2011

Surface Elevation (feet AMSL*): Not Determined
TOC Elevation (feet AMSL*):
Total Depth (feet): 200
Borehole Diameter (inches): 6

*AMSL = Above mean sea level

Depth	Blow Count	Description
		Ground Surface
0–10	3'/min	**Silty Sand with Gravel (SM)** Reddish brown silty sand with gravel, alluvial deposit
10–15	3'/min	
15–20	1'/min	**Lean Clay with Gravel (CL)** Brown lean clay with gravel
20–25	1'/min	**Lean Clay (CL)** Brown lean clay
25–30	1'/min	**Lean Clay with Sand (CL)** Brown lean clay with sand
30–35	1'/min	
35–40	1'/min	**Lean Clay (CL)** Brown lean clay
40–43	<1'/min	**Lean Clay with Gravel (CL)** Brown lean clay with gravel
43–50	1'/min	**Lean Clay with Gravel (CL)** Brown lean clay with basalt fragments

Geologist(s): Robert Wallace
Subcontractor: WDC
Driller/Operator: Joe Zimmer
Method: Air Rotary

WSP Environment & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

Boring Log: A-14

Project: Agrium NuWest CPO

Project No.: 23229

Location: Soda Springs, ID

Completion Date: August 9, 2011

Surface Elevation (feet AMSL*): Not Determined

TOC Elevation (feet AMSL*):

Total Depth (feet): 200

Borehole Diameter (inches): 6

**AMSL = Above mean sea level*

Sample Data

Depth	Sample/Interval	PID/OVM (ppm)	Blow Count	% Recovery
			<1'/min	
			<1'/min	
	R1		6'/hr	39/39/39 (P)
60	R2		10'/hr	87/65/53 (F)
	R3		5'/hr	94/89/58 (F)
70	R4		6.7'/hr	100/58/52 (F)
	R5		1'/hr	64/32/0 (VP)
	R6		3.7'/hr	100/75/68 (F)
80	R7		13'/hr	100/83/59 (F)
	R8		10'/hr	95/71/65 (F)
90	R9		10'/hr	100/28/17 (VP)
	R10		10'/hr	100/87/87 (G)
	R11		8'/hr	98/42/31 (P)
100				

Subsurface Profile

Lithology | **Description** | **Well Details**

Clayey Gravel (GC)
Basalt gravel with clay

Basalt
Green-gray vessicular basalt. Continued with coring drill.

Basalt
Strong, Dark Gray (N3), Massive, Aphanitic, Vessicular, Fresh, Competent, Slightly Fractured

Basalt
Strong, Dark Gray to Medium Gray (N3-N5), Phaneritic, Massive, Slightly Decomposed, Slightly Disintegrated, Moderately Fractured

Basalt
Weak to Moderately Strong, Moderate Brown to Medium Dark Gray (5YR 3/4 - N4), Aphanitic, Vessicular, Massive, Moderately Decomposed, Intensely Disintegrated, Intensely Fractured

Basalt
Moderate strength, Medium Dark Gray to Medium Bluish Gray (N4 - 5B 5/1), Phaneritic, Massive, Slightly Decomposed to Fresh, Slightly Disintegrated to Competent, Slightly Fractured

Basalt
Weak to Very Weak, Grayish Black to Brownish Black (N2 - 5YR 2/1), Aphanitic, Vessicular, Massive, Moderately to Highly Decomposed, Moderately to Intensely Disintegrated, Intensely Fractured

Basalt
Moderately Strong, Olive Black (5Y 2/1), Phaneritic, Massive, Slightly Decomposed, Slightly Disintegrated, Slightly Fractured

Geologist(s): Robert Wallace
Subcontractor: WDC
Driller/Operator: Joe Zimmer
Method: Air Rotary

WSP Environment & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

Boring Log: A-14

Project: Agrium NuWest CPO

Project No.: 23229

Location: Soda Springs, ID

Completion Date: August 9, 2011

Surface Elevation (feet AMSL*): Not Determined

TOC Elevation (feet AMSL*):

Total Depth (feet): 200

Borehole Diameter (inches): 6

**AMSL = Above mean sea level*

Sample Data

Depth	Sample/Interval	PID/OVM (ppm)	Blow Count	% Recovery
	R12		7.5'/hr	90/70/61 (F)
110	R13		23'/hr	100/78/73 (F)
	R14		12.5'/hr	100/58/43 (P)
120	R15		20'/hr	100/95/95 (E)
	R16		-'/hr	66/0/0 (VP)
	R17		-'/hr	100/39/26 (P)
	R18		12'/hr	200/94/94 (E)
130	R19		11.5'/hr	100/83/76 (G)
	R20		18.75'/hr	100/100/100 (E)
140	R21		15'/hr	98/94/94 (E)
	R22		17'/hr	100/93/90 (E)
	R23		30'/hr	100/7/0 (VP)
150	R24		-'/hr	69/0/0 (VP)

Subsurface Profile

Lithology	Description	Well Details
	Basalt Very Weak, Blackish Red (5R 2/2), Phaneritic, Vessicular, Massive, Highly Decomposed/Residual Soil, Intensely Disintegrated, Intensely Fractured	
	Basalt Weak, Blackish Red (5R 2/2), Phaneritic, Massive, Highly Decomposed, Intensely Disintegrated, Moderately Fractured	
	Basalt Moderately Strong, Olive Black (5Y 2/1), Phaneritic, Massive, Moderately Decomposed, Slightly Disintegrated, Moderately Fractured	
	Basalt Very Weak, Dark Yellowish Brown (10YR 6/6), Aphanitic, Vessicular, Massive, Highly Decomposed, Intensely Disintegrated, Very Intensely Fractured	
	Basalt Moderately Strong to Strong, Olive Black to Grayish Black (5Y 2/1 - N2), Phaneritic, Massive, Slightly to Moderately Decomposed, Slightly Disintegrated, Slightly to Moderately Fractued	
	Basalt Moderately Strong to Strong, Medium Dark Gray to Black (N4 - N1), Phaneritic, Massive, Fresh to Slightly Decomposed, Competent to Slightly Disintegrated, Slightly to Intensely Fractured	
	Sandstone Strong, Dark Reddish Brown (10Y 7/4), Fine-grained, Massive, Fresh, Competent, Very Intensely Fractured	

Geologist(s): Robert Wallace
Subcontractor: WDC
Driller/Operator: Joe Zimmer
Method: Air Rotary

WSP Environment & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

Boring Log: A-14

Project: Agrium NuWest CPO

Project No.: 23229

Location: Soda Springs, ID

Completion Date: August 9, 2011

Surface Elevation (feet AMSL*): Not Determined

TOC Elevation (feet AMSL*):

Total Depth (feet): 200

Borehole Diameter (inches): 6

*AMSL = Above mean sea level

Sample Data

Depth	Sample/Interval	PID/OVM (ppm)	Blow Count	% Recovery
	R25		-'/hr	100/17/17 (VP)
	R26		30'/hr	52/0/0 (VP)
160				
	R27		30'/hr	37/15/15 (VP)
	R28		30'/hr	0/0/0 (VP)
170				
	R29		30'/hr	0/0/0 (VP)
	R30		-'/hr	0/0/0 (VP)
180				
	R31		23'/hr	90/0/0 (VP)
	R32		20'/hr	47/65/11 (VP)
190				
	R33		10'/hr	12/7/0 (VP)
	R34		30'/hr	28/8/0 (VP)
200				

Subsurface Profile

Lithology / Description / Well Details

Claystone
Weak, Moderate Greenish Yellow (10Y 7/4), Aphanitic to Course-grained, Laminated, Moderately Decomposed, Moderately Disintegrated, Very Intensely Fractured

Gravel
Metasedimentary rock fragments

Claystone
Very Weak, Olive Gray to Pale Greenish Yellow (10Y 6/2 - 10Y 8/2), Aphanitic to Fine-grained, Thinly bedded to Massive, Highly Decomposed, Moderately to Highly Disintegrated, Very Intensely Fractured *(continued)*

Sandstone
Very Weak, Moderate Olive Brown to Light Gray (5Y 4/4 - N7), Fine-grained, Laminated, Highly Decomposed, Moderately Disintegrated, Intensely to Very Intensely Fractured

Sandy Clay
Poorly Consolidated, Light Gray, No Visible Bedding or Fractures

Sandstone
Weak, Light Olive to Grayish Olive to Pale Greenish Yellow (10Y 5/4 - 10Y 4/2 - 10Y 8/2), Fine to Course-grained, Medium Bedded, Moderately Decomposed, Moderately Disintegrated, Slightly Fractured

Sandstone
Weak, Light Olive (10Y 5/4), Fine-grained, Laminated, Moderately Decomposed, Moderately Disintegrated, Slightly Fractured

Bottom of Boring at 200 feet

Geologist(s): Robert Wallace
Subcontractor: WDC
Driller/Operator: Joe Zimmer
Method: Air Rotary

WSP Environment & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

Boring Log: A-16

Project: Agrium NuWest CPO

Project No.: 23229

Location: Soda Springs, ID

Completion Date: August 17, 2011

Surface Elevation (feet AMSL*): Not Determined

Total Depth (feet): 200

Borehole Diameter (inches): 6

*AMSL = Above mean sea level

Depth	Sample/Interval	PID/OVM (ppm)	Blow Count	% Recovery	Lithology	Description
						Ground Surface
			3'/min			**Organic Soil (OL/OH)**
			2'/min			
			-'/min			**Poorly-Graded Sand with Gravel (SP)** Reddish Brown Sand with Gravel
			1'/min			
			1'/min			**Poorly-Graded Gravel with Sand (GP)** Brown, Poorly-graded Sandstone Gravel with Sand
10			1'/min			
			1'/min			
			1'/min			
20			1'/min			
			1'/min			**Lean Clay with Sand (CL)** Brown Lean Clay with Sand
30			1'/min			
			1'/min			
			1'/min			**Well-Graded Sand with Clay and Gravel (SW-SC)** Brown, Well-graded Sand with Clay and Gravel
			1'/min			
40			1'/min			
			1'/min			
			1'/min			
			1'/min			
50						

Geologist(s): Isaac Pelz
Subcontractor: WDC
Driller/Operator: Joe Zimmer
Method: Air Rotary

WSP Environment & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

Boring Log: A-16

Project: Agrium NuWest CPO
Project No.: 23229
Location: Soda Springs, ID
Completion Date: August 17, 2011

Surface Elevation (feet AMSL*): Not Determined
Total Depth (feet): 200
Borehole Diameter (inches): 6

*AMSL = Above mean sea level

Depth	Sample/Interval	PID/OVM (ppm)	Blow Count	% Recovery	Lithology	Description
			1'/min			**Well-Graded Sand with Clay and Gravel (SW-SC)** Light Gray, Well-graded Sand with Clay and Gravel
			1'/min			
			1'/min			
60			1'/min			
			<1'/min			
70			<1'/min			
			<1'/min			
			<1'/min			**Poorly-Graded Sand (SP)** Light Gray to White, Poorly-graded Sand
80			<1'/min			
			<1'/min			
90			1'/min			
			1'/min			
100						

Geologist(s): Isaac Pelz
Subcontractor: WDC
Driller/Operator: Joe Zimmer
Method: Air Rotary

WSP Environment & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

Boring Log: A-16

Project: Agrium NuWest CPO

Project No.: 23229

Location: Soda Springs, ID

Completion Date: August 17, 2011

Surface Elevation (feet AMSL*): Not Determined

Total Depth (feet): 200

Borehole Diameter (inches): 6

*AMSL = Above mean sea level

Sample Data

Depth	Sample/Interval	PID/OVM (ppm)	Blow Count	% Recovery
			<1'/min	
			1'/min	
			1'/min	
110	R1		<1'/min	33/29/29 (P)
	R2		<1'/min	100/83/93 (E)
120	R3		<1'/min	80/23/16 (VP)
	R4		60'/hr	73/60/60 (F)
130	R5		30'/hr	80/42/42 (P)
	R6		24'/hr	93/52/35 (P)
140	R7		18'/hr	98/63/60 (F)
	R8		42'/hr	60/35/26 (P)
150				

Subsurface Profile

Lithology

Description

Poorly-Graded Sand (SP)
Light Gray to White, Poorly-graded Sand *(continued)*

Claystone Gravel
Light Gray, Claystone Gravel

Claystone
Light Gray Claystone. Changed to coring bit.

Gravel
Basalt/claystone fragments

Siltstone
Light Olive Gray (5Y 6/1), Strong, Massive, Fresh, Competent, Unfractured

Claystone
Light Olive Gray, Moderately Strong, Massive, Slightly Decomposed, Slightly Disintegrated, Moderately Fractured

Sandstone
Light Olive Gray, Weak, Massive to Thinkly Bedded, Fine to Course Grained, Slightly Decomposed, Competent, Moderately Fractured

Claystone
Light Olive Gray, Moderately Strong to Strong, Massive, Fresh to Slightly Decomposed, Slightly Disintegrated, Slightly to Moderately Fractured

Sandstone
Weak, Thinly to Medium Bedded, Fine to Very Fine Grained, Slightly Decomposed, Competent, Moderately Fractured

Claystone
Light Olive Gray, Moderately Strong to Strong, Massive, Fresh to Slightly Decomposed, Slightly Disintegrated, Slightly to Moderately Fractured

Limestone
Light Yellowish Gray, Moderately Strong, Massive, Slightly Decomposed, Slightly Disintegrated, Moderately Fractured

Siltstone

Geologist(s): Isaac Pelz
Subcontractor: WDC
Driller/Operator: Joe Zimmer
Method: Air Rotary

WSP Environment & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

Boring Log: A-16

Project: Agrium NuWest CPO

Project No.: 23229

Location: Soda Springs, ID

Completion Date: August 17, 2011

Surface Elevation (feet AMSL*): Not Determined

Total Depth (feet): 200

Borehole Diameter (inches): 6

*AMSL = Above mean sea level

Depth	Sample/Interval	PID/OVM (ppm)	Blow Count	% Recovery
	R9		12'/hr	70/63/50 (P)
	R10		18'/hr	67/57/57 (F)
	R11		18'/hr	100/78/78 (G)
160	R12		18'/hr	98/92/92 (E)
	R13		12'/hr	100/87/87 (G)
170	R14		36'/hr	85/70/70 (F)
	R15		30'/hr	55/55/42 (P)
180	R16		42'/hr	48/27/27 (P)
	R17		24'/hr	83/80/80 (G)
190	R18		12'/hr	100/57/57 (F)
	R19		18'/hr	95/73/73 (F)
200				

Subsurface Profile

Lithology | **Description**

Light Olive Gray (5Y 6/1), Moderately Strong, Massive, Fresh, Competent, Slightly Fractured

Claystone
Light Olive Gray, Weak to Moderately Strong, Massive (some Limestone interbeds), Fresh to Slightly Decomposed, Slightly Disintegrated, Slightly to Moderately Fractured

Siltstone/Sandstone interbeded
Light Olive Gray, Moderately Strong, Massive to Medium Bedded, Fresh, Competent, Slightly Fractured

Limestone
Light Yellowish Gray, Moderately Strong to Strong, Massive to Thinly Bedded, Fresh to Slightly Decomposed, Competent, Medium to Course Grained, Slightly Fractured

Sandstone
Light Olive Gray, Moderately Strong, Medium Grained, Massive, Fresh, Competent, Unfractured

Claystone
Light Olive Gray, Moderately Strong, Massive, Fresh, Competent, Unfractured

Sandstone
Light Olive Gray, Moderately Strong, Medium Grained, Massive, Fresh, Competent, Unfractured

Claystone
Light Olive Gray, Moderately Strong, Massive, Fresh, Competent, Unfractured

Claystone
Light Olive Gray, Very Weak, Massive, Highly Decomposed, Intensely Disintegrated, Unfractured, Yellow Brown Mineral Deposits

Finely Laminated Sequence
Finely Laminated Repeating Sequence, Coursening Downward, Moderately Strong, Fresh, Slightly Disintegrated, Unfractured

Geologist(s): Isaac Pelz
Subcontractor: WDC
Driller/Operator: Joe Zimmer
Method: Air Rotary

WSP Environment & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

Boring Log: A-16

Project: Agrium NuWest CPO

Project No.: 23229

Location: Soda Springs, ID

Completion Date: August 17, 2011

Surface Elevation (feet AMSL*): Not Determined

Total Depth (feet): 200

Borehole Diameter (inches): 6

**AMSL = Above mean sea level*

Depth	Sample/Interval	PID/OVM (ppm)	Blow Count	% Recovery	Lithology	Description
						Claystone Medium Light Gray (N5), Moderately Strong, Massive, Fresh, Slightly Disintegrated, Unfractured
						Finely Laminated Sequence Finely Laminated Repeating Sequence, Coursening Downward, Moderately Strong, Fresh, Slightly Disintegrated, Unfractured
210						***Claystone*** Medium Light Gray (N5), Moderately Strong, Massive, Fresh, Slightly Disintegrated, Unfractured
						Siltstone Light Olive Gray (5Y 6/1), Moderately Strong, Massive, Fresh, Competent, Slightly Fractured
220						***Sandstone*** Weak, Thinly to Medium Bedded, Fine to Very Fine Grained, Slightly Decomposed, Competent, Moderately Fractured
						Siltstone Light Olive Brown, Moderately Strong, Massive, Slightly Decomposed, Slightly Disintegrated, Moderately Fractured
230						***Limey Claystone*** Light Yellowish Gray, Moderately Strong, Massive to Finely Bedded, Slightly Decomposed, Slightly Disintegrated, Unfractured
						Limestone Moderately Strong, Massive, Fresh, Competent, Unfractured
						Bottom of Boring at 200 feet
240						
250						

Geologist(s): Isaac Pelz
Subcontractor: WDC
Driller/Operator: Joe Zimmer
Method: Air Rotary

WSP Environment & Energy
11190 Sunrise Valley Drive
Suite 300
Reston, VA 20191

Appendix B – Colog’s Final Report of Geophysical Survey Results

Geophysical Logging Results
WSP Environment and Energy
Nu-West Industries – 3 Up-gradient Wells
Soda Springs, ID

Prepared for:
WSP Environment and Energy
October 4, 2011

Prepared by:
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- 3-Arm Caliper and Optical Televiewer Logs
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1.0 Introduction

On September 8-10, 2011, wells A-14, A-15 and A-16 were geophysically logged at the Nu-West Agrium site near the town of Soda Springs, Idaho. The following table summarizes the construction of each well and the geophysical data collected.

Well	Dates Geophysically Logged	Logger TD (ft below TOC)	Bottom Casing Depth (ft below TOC)	Approximate Water Level (ft below TOC)	Geophysical Logs Recorded
A-14	8-9 Sept 2011	202.9	60.8	~53.3	Natural Gamma SP/SPR/Resistivity Temp/Fluid Resistivity 3-Arm Caliper Compensated Density Thermal Neutron Full-Waveform Sonic Heat-Pulse Flowmeter Spinner Flowmeter
A-15	9-10 Sept 2011	152.3	58.1	~54.4	Natural Gamma Temp/Fluid Resistivity 3-Arm Caliper Compensated Density Thermal Neutron
A-16	8-9 Sept 2011	201.7	113.8	~100.8	Natural Gamma SP/SPR/Resistivity Temp/Fluid Resistivity 3-Arm Caliper Compensated Density Thermal Neutron Full-Waveform Sonic Heat-Pulse Flowmeter

Geophysical data collection was performed in accordance with Colog’s general operating procedures.

2.0 Methodology

The following sections describe the geophysical probes used by Colog for this project and their general operating and physical principles.

2.1 Natural Gamma

Natural gamma logging was performed with a Mount Sopris 2PGA/2PEA probe, which measures natural gamma, spontaneous potential, single-point resistance and normal resistivities in the same logging pass.

The natural gamma log (also known as gamma or gamma ray log) provides a measurement recorded in counts per second (CPS), that is proportional to the natural radioactivity of the formation. Actual counts depend upon the detector size and efficiency but are often normalized in API units. 200 API units equal the detector response in a specially constructed physical model designed to simulate the typical shale. For most of COLOG's gamma probes, 1 API unit is approximately equal to 1.25 CPS. The depth of investigation for the gamma log is typically 10 to 12 inches. Gamma logs provide formation clay and shale content and general stratigraphic correlation in sedimentary formations. In general, the natural gamma ray activity of clay-bearing sediments is much higher than that of quartz sands and carbonates. Gamma logs are also used in hard rock environments to differentiate between different rock types and in mining applications for assessment of radioactive mineralization such as uranium, potash, etc.

Gamma radiation is measured with scintillation NaI detectors. The gamma-emitting radioisotopes that naturally occur in geologic materials are Potassium40 and nuclides in the Uranium238 and Thorium232 decay series. Potassium40 occurs with all potassium minerals, including potassium feldspars. Uranium238 is typically associated with dark shales and uranium mineralization. Thorium232 is typically associated with biotite, sphene, zircon and other heavy minerals.

The usual interpretation of the gamma log, for hydrogeology applications, is that measured counts are proportional to the quantity of clay minerals present. This assumes that the natural radioisotopes of potassium, uranium, and thorium occur in exchange ions, which are attached to the clay particles. Thus, the correlation is between gamma counts and the cation exchange capacity (CEC). Usually gamma logs show an inverse linear correlation between gamma counts and the average grain size (higher counts indicate smaller grain size, lower counts indicate larger grain size). This relation can become invalid if there are radioisotopes in the mineral grains themselves (immature sandstones or arkose), and if there are differences in the CEC of clay minerals in the different parts of the formation. Both of these situations are possible in many environments. The former situation would most likely occur in basal conglomerates composed of granitic debris, and the latter where clay occurs as a primary sediment in shale and another as an authigenic mineral deposited in pore spaces during diagenesis.

The assumption of a linear relationship between clay mineral fraction in measured gamma activity can be used to produce a shale fraction calibration for a gamma log in the form:

$$Csh = (G-Gss) / (Gsh - Gss)$$

Where Csh is the shale volume fraction, G is the measured gamma activity; Gss is the gamma activity in clean sandstone or limestone; Gsh is the gamma activity measured in shale.

Calibration of the gamma logging tool is usually performed in large physical models such as the API test pits in Houston, or the DOE uranium calibration test pits. In hydrogeology, the gamma measurement is usually a relative log and quantitative calibrations are not routinely performed. However, the stability and repeatability of the natural gamma measurement is routinely checked with a sleeve of known radioactivity. It is also common to routinely check the gamma log by repeat logging a section of a well. Natural radioactive decay follows a Gaussian distribution; that is, approximately 67% of the radioactive response occurs within ± the square root of the count rate. For instance, if a background radiation of 100 CPS is being measured, there is approximately ± 10 CPS variability.

Fundamental assumptions and limitations inherent in these procedures are as follows:

- The natural gamma ray log, as with all nuclear or radiation logs, have a fundamental advantage over most other logs in that they may be recorded in either cased or open holes that are fluid or air filled. Borehole fluid and casing may attenuate the gamma values.

Excessive borehole rugosity, often caused by air drilling, may degrade natural gamma ray log

2.2 Electrical Measurements – SP, SPR and Normal Resistivities

Electrical logging was performed with a Mount Sopris 2PGA/2PEA probe, which measures natural gamma, spontaneous potential, single-point resistance and normal resistivities in the same logging pass.

All electrical logs require the presence of the borehole fluid to carry the current from the probe to the formation, and therefore these devices only operate below fluid level. Quantitative formation electrical resistivity, spontaneous potential, and qualitative single point resistance can be measured with a combination tool. The operational features of each measurement are discussed under the measurement heading.

16-inch and 64-inch Normal Resistivities

Formation resistivity is dependent on the fluid salinity, permeability, and connected fracture paths within the depth of investigation of the measurement. Measured resistivity is also controlled by particle surface conduction in clastic environments. The resistivity measurement decreases in larger diameter boreholes and areas in which the borehole has been broken out, and/or highly fractured. The above responses allow interpretation of lithologic types, correlation of beds, estimation of fluid quality and possible fractured zones.

A constant current is supplied to the downhole current electrode and the resulting voltage drop is measured on the return electrodes 16" and 64" away from the current electrode. The resistivity of the surrounding media (which includes the borehole fluid) is derived from Ohm's Law and the geometry of the electrode arrangement. The static electric field which results from the geometric arrangement of electrodes is ideally a sphere 16" or 64" in radius (for the short and long normal functions respectively). The presence of the borehole diameter and mudcake affects the measurement sphere by decreasing the lateral extent, and increasing the vertical extent. Borehole corrections based on the borehole fluid resistivity can be made, but these corrections do not address the effects of vertical averaging. Accurate interpretation of the logs minimizes this averaging effect. The influence of the borehole size becomes less with smaller diameter boreholes. Calibration of the 16" and 64" normal resistivities is performed in the field with a resistance box which tests a range of known resistivities from 0.0 ohm-m to 1,000 ohm-m.

Single Point Resistance (SPR)

The SPR measurement is controlled by rock and fluid parameters in much the same way as resistivity logs. SPR is a simple system of two electrodes (the resistivity current electrode) and a surface electrode. Current is passed through the formation and voltage differences are measured between the two electrodes. The measured resistance includes the resistance of the cable, borehole fluid, and the formation around the borehole. The current density is higher near the borehole electrode and surface electrode. Since the current density at the surface electrode is constant, formation variations close to the probe produce the resistance changes visible on the logs. Since there is a single downhole electrode, not an array, the log effectively shows a point measurement. This gives a very "responsive", high vertical resolution measurement. Though the single point resistance cannot be calibrated quantitatively, its instantaneous response is a good boundary indicator, and does show a more well-defined response than the 16" or 64" normal resistivities.

Spontaneous Potential (SP)

The SP is a measurement of the naturally occurring potential in the borehole. This naturally occurring potential is most often caused by a concentration gradient between the borehole fluid and formation fluid (electro-chemical), and requires the presence of a clay rich/porous media interface to occur.

Reduction/oxidation (redox) interfaces and streaming potentials (electro-kenetic) caused by the flow of fluid in or out of the borehole are also causes for the occurrence of spontaneous potential.

In fresh water environments where the drilling fluid is natural or the salinity is near the formation pore fluid salinity the electro-chemical potential is minimized. The absence of sulfide mineralization or fluid movement into or out of the formation may minimize the redox and streaming potentials.
Spontaneous potential logging was performed with a Mount Sopris 2PGA probe, which measures natural gamma, spontaneous potential and single-point resistance in the same logging pass.

2.3 3-Arm Caliper

3-arm caliper logging was performed with a Mount Sopris QL-40 stackable CAL tool.

The caliper log represents the average borehole diameter determined by the extension of 3 spring-loaded arms. The measurement of the borehole diameter is determined by the change in the variable pot resistors in the probe, which are internally connected to the caliper arms.

Caliper logs may show diameter increases in cavities and, depending on drilling techniques used, in weathered zones. An apparent decrease in borehole diameter may result from mud or drill-cutting accumulation along the sides of the borehole (mudcake), a swelled clay horizon or a planned change in drill bit size. The bottom of the boring can also induce a small diameter reading from the caliper due to the caliper leaning up against on side of the borehole. The caliper log is often a useful indicator of fracturing. The log anomalies do not directly represent the true in-situ fracture size or geometry. Rather, they represent areas of borehole wall breakage associated with the mechanical weakening at the borehole-fracture intersection. Caliper anomalies may represent fractures, bedding planes, lithologic changes or solution openings. Generally, in solid bedrock, caliper log anomalies indicate the intervals where fractures intersect boreholes.

Colog records the caliper log with either a single-arm caliper measurement using the decentralization arm of the density probe or a separate stand-alone three-arm caliper. Calibrations of the probe are done routinely on the bench and in the field directly before the tool is placed into the borehole. Calibration standards consist of rings of known diameters that are placed over the extended arms as the tool response at these diameters is recorded. Additionally, as with other geophysical measurements, a repeat section may be collected and compared with the original logs for consistency and accuracy.

Fundamental assumptions and limitations inherent in these procedures are as follows:

- Excessive borehole diameters (greater than 36 inches) may limit the range of borehole caliper measurements. Holes greater than 12 inches must be logged with extended arms for hole diameters up to 36 inches.

- Since the caliper probe is an electro-mechanical device, a certain amount of error is inherent in the measurement. These errors are due to: 1) averaging hole diameter using three arms, 2) non-linearity of the measurement resistor, 3) tolerance in the mechanical movement of the caliper arms (mechanical hysteresis).

2.4 Temperature and Fluid Conductivity

Temperature and fluid conductivity logging was performed with a Mount Sopris QL-40 stackable FTC tool.

Geothermal gradients in the near surface earth are usually dominated by conduction, and are generally linear increasing with depth due to the relative constancy of the thermal conductivity of earth materials. Convective heat flow within the borehole fluid is caused by formation fluid entering or leaving the borehole at some permeable interval. Therefore, deviations from the linear thermal gradient can be attributed to fluid movement. Both the thermal gradient and fluid resistivity profile of the borehole fluid can be obtained with the same probe. The temperature is measured with a thermistor and the fluid resistivity is measured with a closely spaced Wenner electrical array.

Slope changes in both the temperature and fluid resistivity logs may be indicative of fluid flow between the formation and the borehole. Both responses are effected by drilling method, time since circulation, mud type or additives and well development procedures.

A differential temperature log is a calculated curve that amplifies slight slope changes in the temperature gradient and can assistance in the interpretation of the fluid temperature log. As the probe is lowered downhole, small changes in the slope of the temperature curve are identified by a differential curve that is plotted from a center zero line. The differential temperature is constructed by using a temperature point at one depth and subtracting a point at a lower depth throughout the entire logged interval.

(temperature value Depth 1) **-** (temperature value Depth 2) = differential value

In real time the differential values are calculated across the acquisition digitizing interval (e.g. 0.1 to 0.5 ft). Because of the small digitizing interval the calculated real time differential curve may only identify larger temperature gradient deviations. Another differential temperature can be constructed in post processing over a larger sample interval (sometimes up to 2 ft). This log commonly provides a more diagnostic differential curve and is used frequently in the temperature profile interpretation.

The fluid resistivity in the borehole is controlled primarily by the salinity. Therefore, salinity stratification, or the introduction of a fluid of different water quality into the borehole, can be observed by changes in the fluid resistivity log. Often, the exchange of fluid between the formation and the borehole, influences both the temperature and the fluid resistivity so that the response is evident in both logs.

Temperature corrected resistivity can be converted to equivalent NaCl salinity in parts per million (Bateman and Konen, 1977). A salinity profile can then be plotted which indicates the general water quality trend of the borehole fluid. If the assumption is made that the borehole fluid is in equilibrium with the formation fluid, then the borehole salinity profile can be interpreted as a formation fluid salinity profile. Differences between these profiles from well to well, may contain information concerning the extent of hydraulic connectivity in the area.

Fundamental assumptions and limitations inherent in these procedures are as follows:

- The borehole temperature log is usually the first log run in a borehole and, unlike virtually all other logs, is run while the probe is moving down the hole. The exception to running this probe first, however, would be if any optical measurement is to be acquired. The idea is that the logging of the temperature/resistivity probe may stir up the wellbore fluids inhibiting the optical device.

- The recorded borehole temperature is only that of the fluid surrounding the probe, which may or may not be representative of the temperature in the surrounding rocks.

- In most wells the geothermal gradient is considerably modified by fluid movement in the borehole and adjacent rocks.

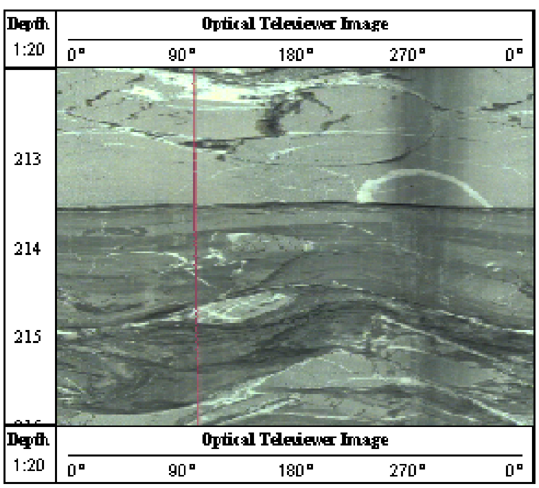
- Temperature logs are generally recommended for uncased fluid-filled boreholes, but may be used in fluid-filled cased wells for some applications.

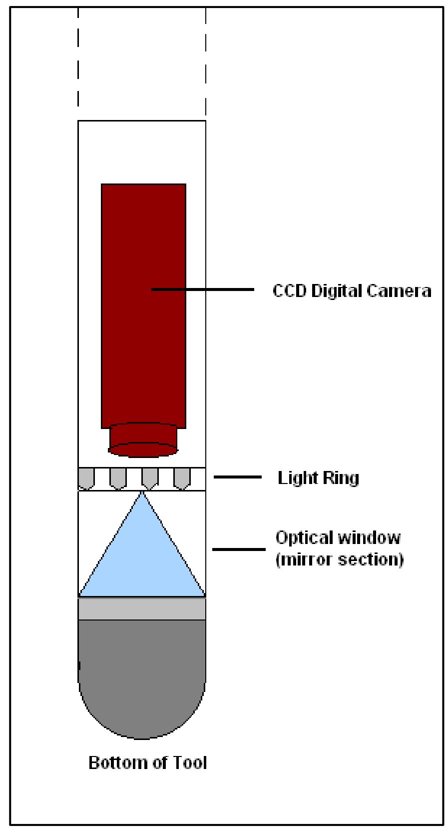
2.5 Optical Televiewer (with Interpretation Section)

The OBI-40 optical televiewer, from Advanced Logic Technologies (ALT), provides one of the highest resolutions available for fracture and feature analysis in boreholes. Precise dip direction and angle measurements of bedding, fractures, and joint planes, along with other geological analyses, are possible. The optical televiewer technology is based on direct optical observation of the borehole wall face and can be utilized in both air and clear fluid filled boreholes

<u>Optical Televiewer – Theory of Operation</u>

The OBI-40 optical televiewer provides a detailed, oriented optical image of the borehole wall. A small ring of lights illuminates the borehole wall allowing a camera to directly image the borehole wall face. A conical mirror housed in a clear cylindrical window focuses a 360° optical "slice" of the borehole wall onto the camera's lens. As the optical televiewer tool is lowered down the hole, the video signal from the camera is transmitted uphole via the wireline to the recording instrumentation.





Figures: Example of OBI40 optical Televiewer data (left) and sketch of OBI40 optical tool head (right).

The signal is digitized in real time by capturing up to 720 pixels from the conical optical image. A digital magnetometer and accelerometer package is used to determine the orientation of the probe, and thus the digital image, for each conical image capture. The conical image rings are stacked and unwrapped to a 2-D, oriented image of the borehole wall.

Precise borehole trajectory/deviation and image orientation are achieved using a 3-axis magnetometer and three accelerometers. When the tool is well-centralized, azimuthal accuracy is to ±1.0 degrees and inclination accuracy is to ±0.5 degrees. Deviated or rugous boreholes and outside magnetic interference can contribute to reduced orientation accuracy of the tool, and thus the oriented image. The pink line seen in the example data above represents a fixed point on the tool; it is used in orienting the data with respect to magnetic north.

Tool image colors are calibrated in shop to true-color, however, varying light conditions downhole often lead to color images that are somewhat false-colored. This should be taken into account when reviewing images.

Main applications of the optical televiewer include: fracture detection and evaluation, detection of thin beds, determination of bedding dip, lithological characterization, and casing inspection.

Understanding 2-D Televiewer Images

For both the optical and acoustic televiewer, the 2-D picture of the borehole wall is unwrapped from north to north. Planar features that intersect the borehole appear to be sinusoids on the unwrapped image. To calculate the dip angle of a fracture or bedding feature, the amplitude of the sinusoid (h) and the borehole diameter (d) are required. The angle of dip is equal to the arc tangent of h/d, and the dip direction is picked at the trough of the sinusoid.

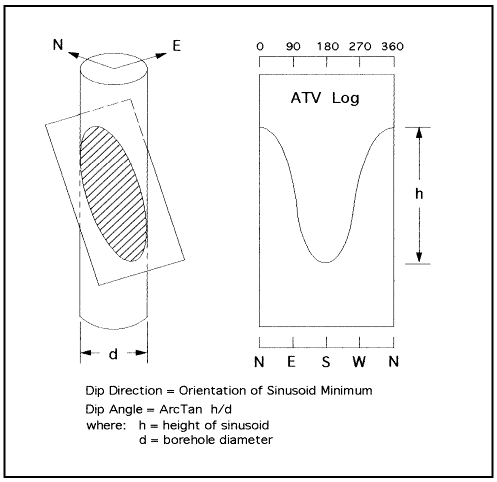


Figure: Geometric representation of a north-dipping fracture plane and corresponding log.

Interpreting Optical Televiewer Data

Sinusoidal features are picked throughout the boreholes by visual inspection of the digital optical televiewer images using the interactive software WellCAD. These sinusoidal feature *projections* can directly overlay the televiewer images or be plotted alongside the televiewer images.

The features can also be represented by *tadpoles*. The tail of the tadpole points in the azimuthal direction of dip, where north is up, east is 90^{o} to the right, etcetera. The head of the tadpole is located vertically on the plot, at the projection's inflection point, that is, halfway between the peak and the trough depth of the sinusoidal projection. The horizontal head location represents the dip angle, with shallow features near the left side of the plot and steeper features near the right side.

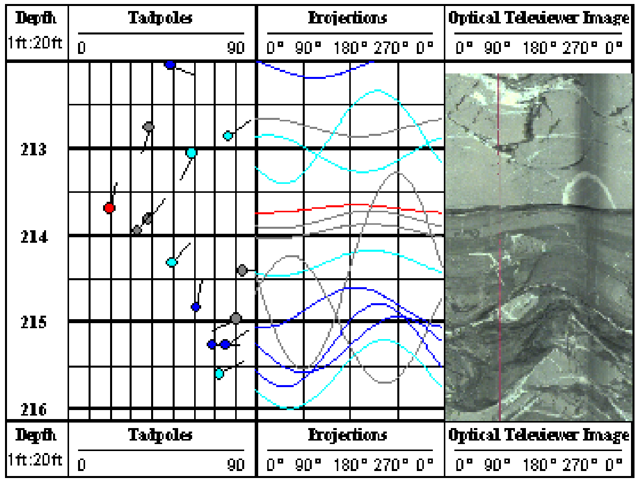


Figure: Example projections and tadpoles for corresponding optical televiewer data sets.

The WellCAD software calculates the true feature orientation (dip direction and angle) in both deviated and vertical boreholes. Depths are assigned to the fractures or bedding features at the inflection points (middles) of the sinusoids. Features are subjectively ranked for flow potential using *COLOG's Ranking System for Optical Televiewer Features*, included in this report. The features picked, along with their assigned ranks, orientations and depths are exported and presented in tables for each well. Orientations are based on magnetic north and are not corrected for magnetic declination, unless specified.

From the feature data tables, stereonet plots and rose diagrams are generated, as necessary. Stereonet plots and rose diagrams provide useful information concerning the statistical distribution and possible patterns or trends that may exist from the optical and/or acoustic televiewer feature orientation data set.

Rose Diagrams

A rose diagram is a polar diagram in which radial length of the petals indicates the relative frequency (percentage) of observation of a particular angle or fracture dip direction or range of angles or dip directions. Rose diagrams are used to identify patterns (if any) in the frequency of dip angles or directions for a particular data set. The following rose diagrams and stereonet plots all come from the same data set to help illustrate the relationships between the plot types.

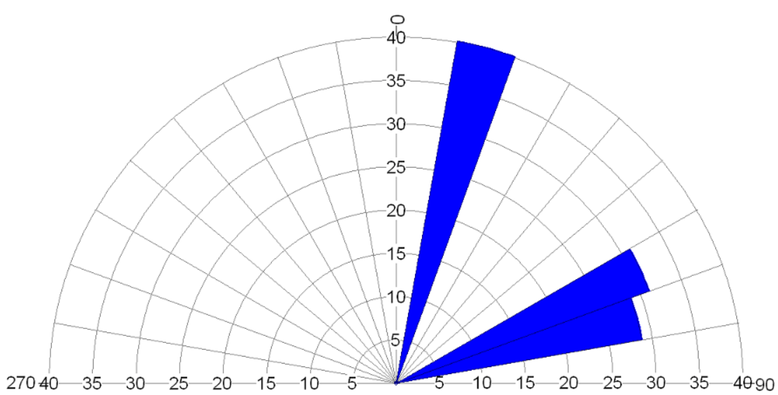


Figure: Example rose diagram from an optical televiewer data set illustrating the frequency (%) of dip angles.

With a quick glance at the above rose diagram of dip angle values, one can see two distinct sets of dip angles; one set with lower dip angles and one set with higher dip angles. Specifically, 40 percent of the features have a dip angle between 10^o and <20^o, and 60 percent of the features have a dip angle between 60^o and <80^o. The left-hand side of the above rose diagram will always be blank by convention of positive dip angle values only.

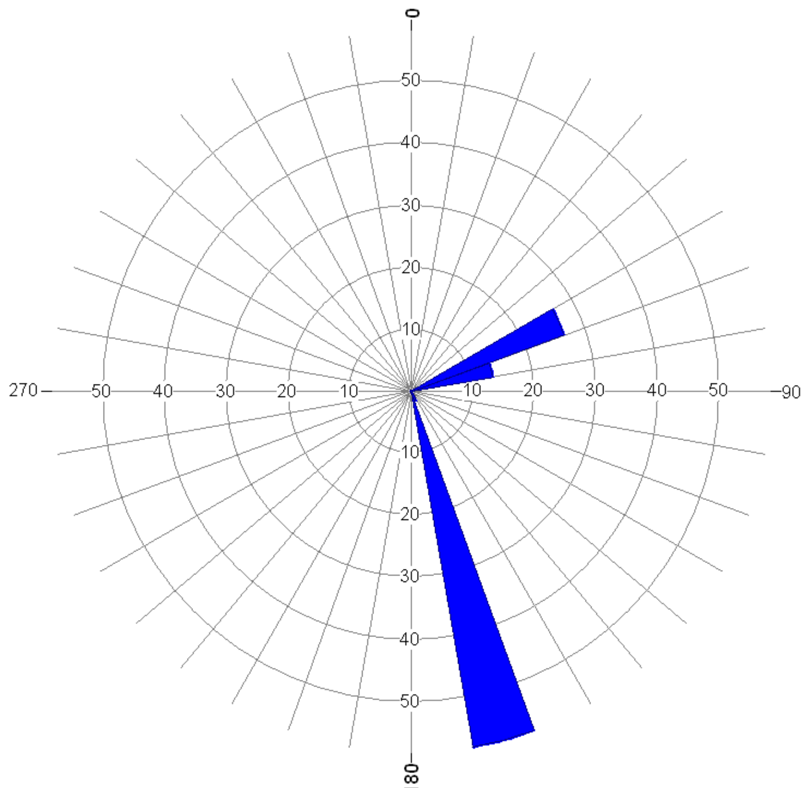


Figure: Example rose diagram from an optical televiewer data set illustrating the frequency (%) of dip direction (azimuth).

With a quick glance at the above rose diagram of dip direction values, one can see that the features (and/or fractures) in this data set have two primary dip directions. Specifically, 40 percent of the features dip to the east-northeast between 60^o degrees and <80^o in azimuth and 60 percent of the features dip to the south-southeast between 160^o and <170^o in azimuth.

Stereonets

For stereonets, Colog utilizes a southern-hemisphere projected, equal-area Schmidt net to plot the poles to the feature planes. These plots are often used in plotting geologic data such as the dips and orientations of structural features. Here, the azimuthal angle indicates dip direction of the plane's pole (which dips 180 degrees opposite in azimuth from the plane's dip direction at a complementary angle). The distance from the center indicates the dip magnitude. The further from the center the steeper the dip angle; the closer to the center the more horizontal the feature is.

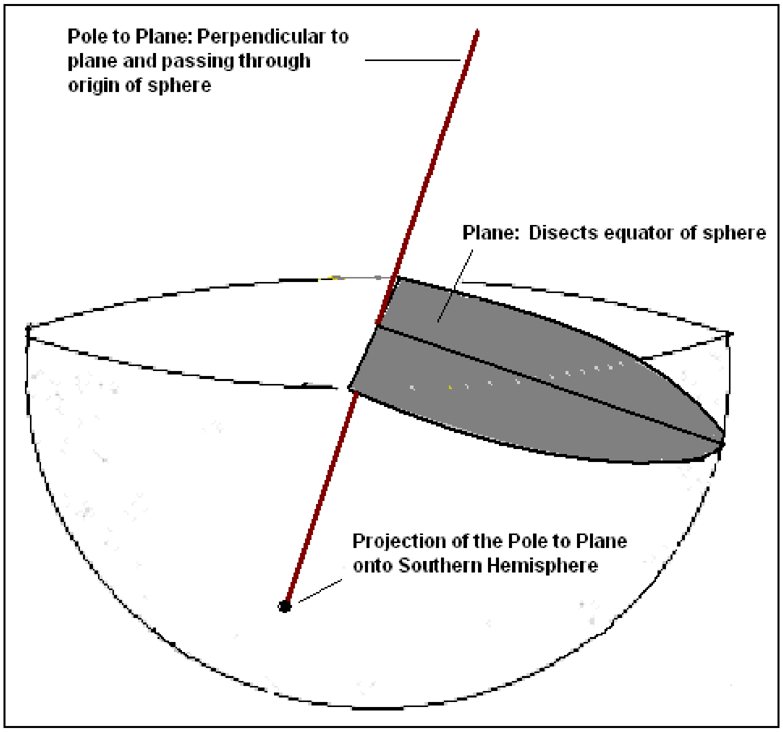


Figure: The above cartoon demonstrates the relationship between a plane and its pole, as projected onto the southern hemisphere of a sphere.

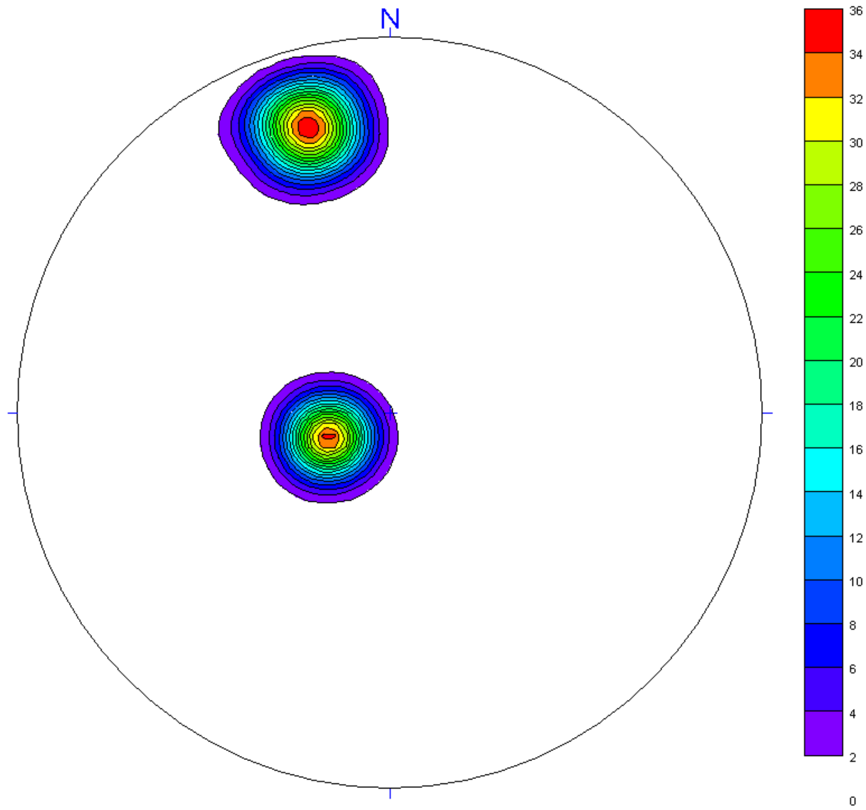
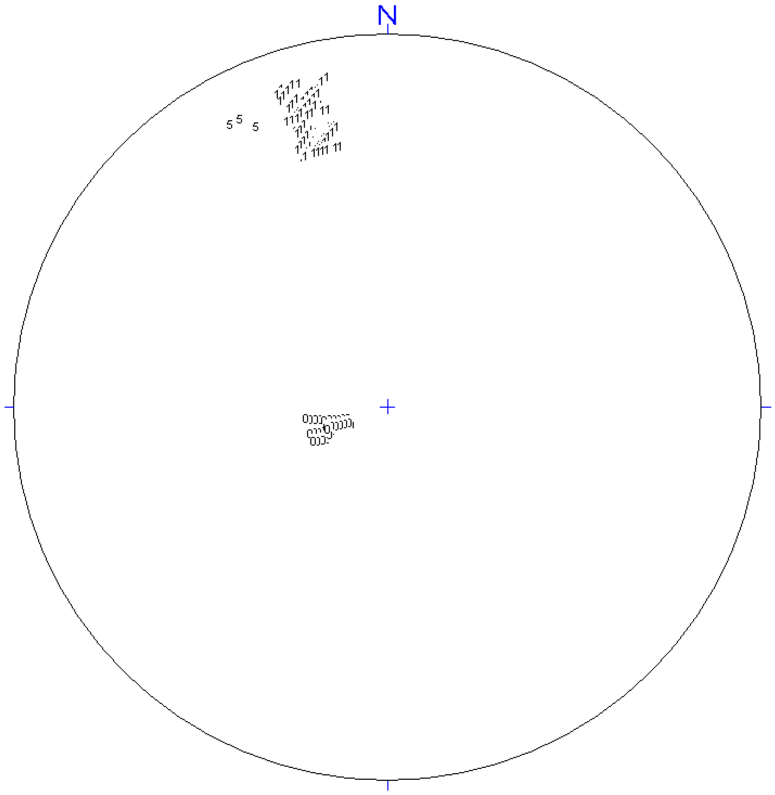


Figure: Example stereonet from an optical televiewer data set illustrating the frequency (%) of dip direction and dip angle.

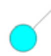
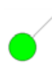
The figure above is an example stereonet diagram from the same televiewer data set of fractures and features as used previously to describe rose diagrams. It was created by binning the density (frequency) of poles per area. The figure below indicates, with a quick glance, that two distinct patterns exist in the example data set. A cluster of fractures/features with similar dip directions of approximately 160-170 degrees with steep dip angles of around 60-80 degrees is apparent. A second cluster is apparent with similar dip directions of approximately 60-80 degrees with moderate dip angles of approximately 10-20 degrees. The white areas indicate low to zero density of poles.



Colog also often provides a Schmidt net with the qualitative rank of each fracture/feature plotted at the location of its planar pole. Please refer to the *Ranking System for Optical Televiewer Features*, included in the report, for an explanation of the qualitative ranks assigned each optical televiewer feature identified.

With a quick glance at the above Schmidt net, one can see that the low dip angle features which dip to the east-northeast are bedding features, ranked “0”; the high dip angle features dipping to the south-southeast are primarily weak or partial fractures, ranked “1”; and there are several major fracture zones, ranked “5”, with strike/dip very similar to the majority of the partial/weak fractures in the well.

Ranking System for Optical Televiewer Features

	Rank	Color Code	Observation	Flow Rating System
	0	Gray 	Non-flow feature (bedding, healed fracture, staining, foliation, vein, etc.)	Sealed, no flow
	1	Cyan 	Weak feature (not continuous around the borehole)	Partial open crack
	2	Blue 	Clean, distinct feature	Continuous Open crack
	3	Red 	Distinct feature with apparent aperture	Wide open crack Or cracks
	4	Magenta 	Very distinct, wide possible interconnected fracture	Very wide crack or multiple interconnected fractures
	5	Green 	Major fracture zone with large openings.	Major fracture with large openings or breakouts

This ranking system is based on a system developed and applied by Paillet (USGS, WRD, Borehole Research Project) as a subjective evaluation of permeability potential. In general, the higher the rank, the greater the likelihood of fracture interconnection and subsequent increased permeability. Tadpoles represent individual features, where the tail points in the direction of dip (clockwise from the top, 0-359). The head is positioned vertically according to the median depth of the feature and positioned horizontally according to the feature dip angle (0-90 from horizontal).

2.6 Full-Waveform Sonic

Digital full-waveform sonic (FWS) data is acquired with a Mount Sopris Instruments 2SAF probe configured with three receivers at fixed separations of 3-ft, 4-ft and 5-ft from the sonic transmitter. The acquisition software allows the real-time viewing of the waveforms as they are written directly to hard disk. The waveforms can also subsequently be viewed and processed for amplitude, frequency, and velocity information. Functionality and repeatability of the probe is monitored by logging in an ungrouted, fluid-filled, steel pipe, and by repeat logging of boreholes at each project.

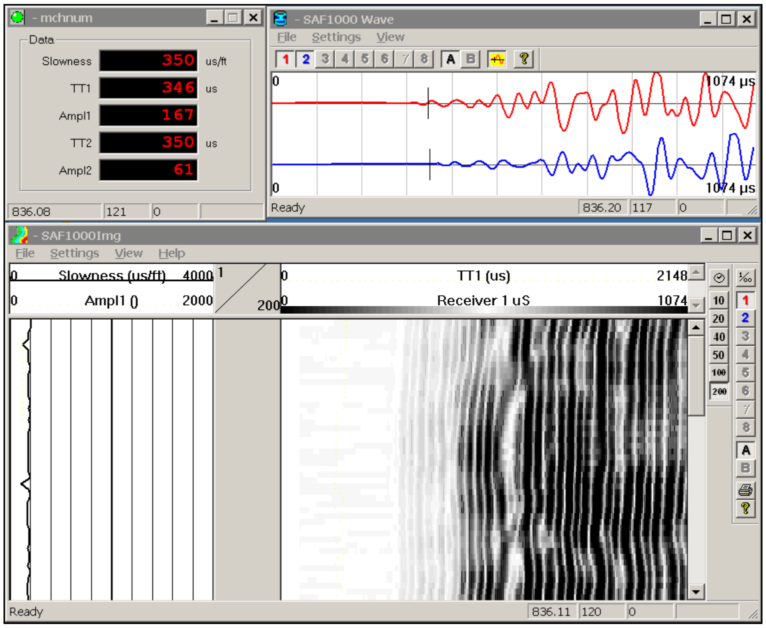


Figure: Real-time presentation from the sonic acquisition software, illustrating the output of a 2SAF configured with two receivers.

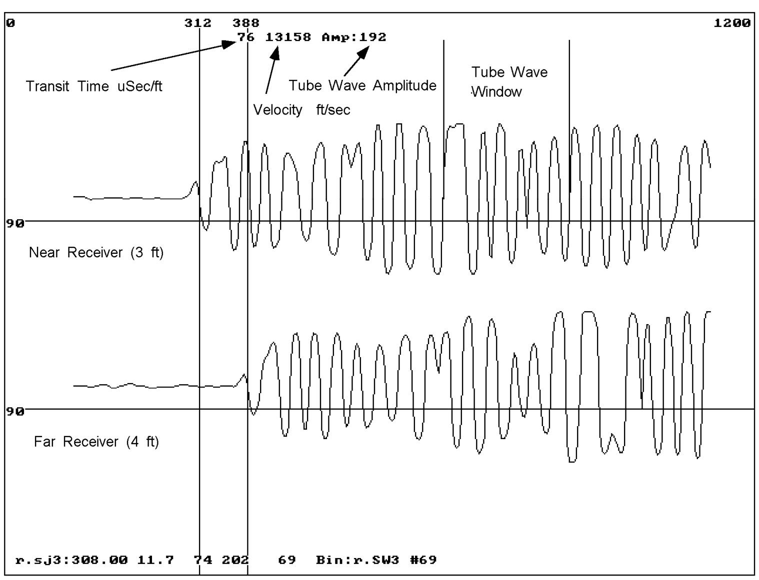


Figure: Example of a typical waveform pair with the tube wave annotated.

The FWS log, recorded in the time domain at two or three downhole receivers, consists of interacting sonic waves generated by a 15-30 kHz (user variable) acoustic energy pulse from the downhole transmitter. Sonic logs can only be obtained in the fluid-filled portion of the borehole, and the propagation of these waves is controlled by the borehole wall/fluid interface, at which head waves are critically refracted and complicated reflections occur.

Sonic transit time, or slowness, is the compression-wave travel time, per foot of rock, and represents the inverse of velocity (i.e., greater transit time equals slower velocity). Often referred to as "delta-T" because it is the difference in arrival times between two receivers spaced one foot apart, transit time can be used to characterize rock lithology, consolidation, and presence of discontinuities. These characterizations, however, usually require calibration from core data unless regional relationships are available. Transit times are also used to help in the processing of seismic reflection and refraction data.

The tube wave is a guided fluid wave that travels along the borehole wall/fluid boundary at a velocity slightly slower than the speed of sound in water.

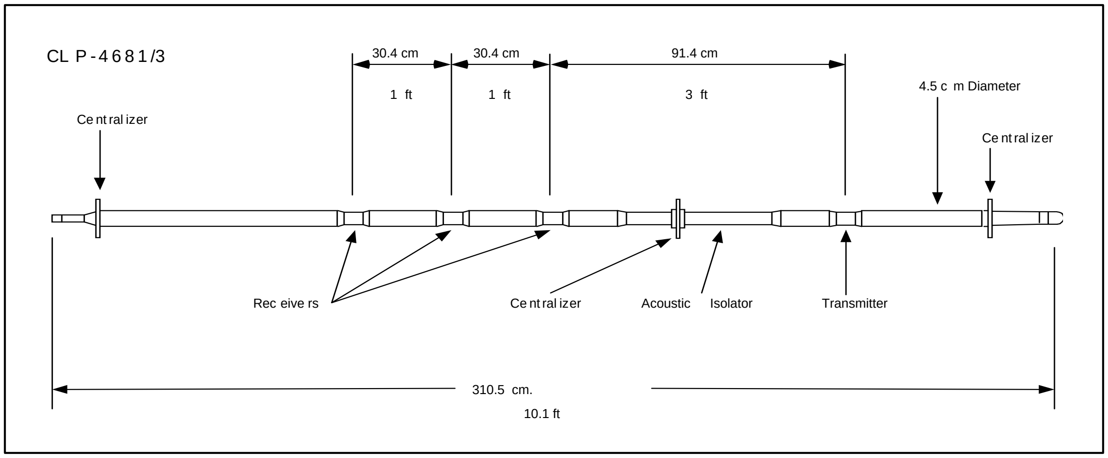


Figure: Probe schematic for the 2SAF sonic probe.

Vertical stacking of the individual waveforms creates the full waveform display, which uses a banded presentation to represent the sinusoidal nature of sonic waves. By convention, black bands represent high amplitude waves above the centerline, dark gray is the low amplitude portion of the positive wave, while light grey is the low amplitude portion of the negative wave below the centerline, and white is the high amplitude portion of the negative wave. The degree of discontinuity of the rock is reflected by the deviation from parallel banding in the FWS VDL display. The velocities and other information obtained from sonic logs are used to determine the lithology, formation porosity, cement bonding, formation weathering, rock strength, and to identify fractures.

2.7 Focused Density (or Dual Density)

Density logging was performed with a Robertson Geologging FDGS probe.

The principle behind density logging is the detection of Compton-scattered gamma rays that originate from a small radioactive source housed in the probe Figure D-1. The intensity of the radiation reflected back to the detectors is primarily a function of the bulk density of the media in which the gamma rays are introduced and scattered.

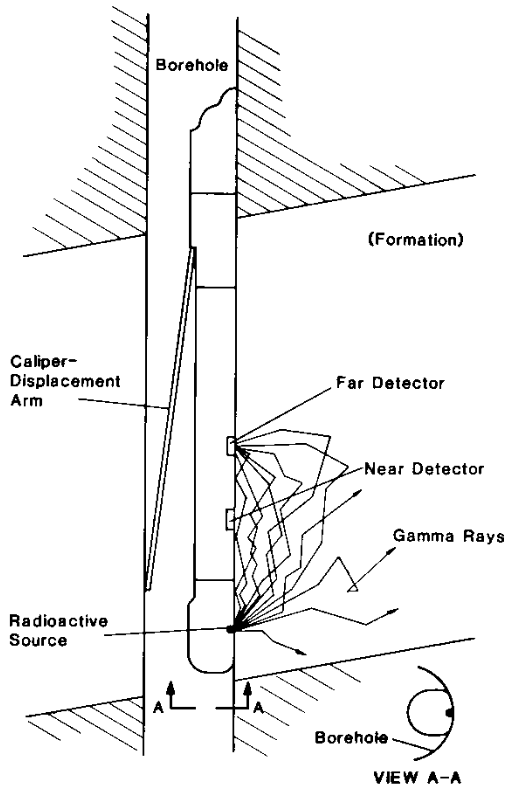


Figure D-1: Probe schematic in the borehole for the dual density (focused) probe.

Calibration of the density tool is accomplished by measuring the reflected gamma radiation from materials of known densities. COLOG routinely performs shop calibrations using lucite and aluminum blocks and periodically checks those calibrations in the USBM calibration test holes at the Denver Federal Center, Colorado.

Fundamental assumptions and limitations inherent in these procedures are as follows:

- The focused density gamma/gamma log, as with all nuclear or radiation logs, have a fundamental advantage over most other logs in that they may be recorded in either cased or open holes that are fluid or air filled. Borehole fluid and casing may attenuate the gamma values.

- Excessive borehole rugosity, often caused by air drilling, may degrade the focused density gamma/gamma ray log results.

2.8 Thermal Neutron (or Dual Neutron)

Neutron logging was performed with a Robertson Geologging DNNS probe. Functionality and design is nominally the same as that of the dual density probe, schematically shown in Figure D-1 above, except that the DNNS probe does not have a caliper arm.

High energy neutrons are generated by a 1 or 3 curie Am^{241}-Be radioactive source attached to the end of the probe. These neutrons interact with the media which surrounds the probe including the borehole fluid and formation. The significant aspects of that interaction are the loss of energy due to collisions with hydrogen atoms and the subsequent capture of the neutrons by various nuclei (including hydrogen). The detector in the neutron tool is spaced 14" from source and counts only the low energy (thermal) neutrons which have not been captured. Within a certain range (unspecified) the thermal neutron count rate is inversely proportional to the population of hydrogen atoms surrounding the tool. Therefore, for a constant borehole size the neutron count rate can be related to total water content surrounding the tool, registering higher counts for lower water content. The inverse counts vs. water content relationship can be explained in terms of the degree of neutron capture that occurs. For example, lower water content captures fewer low energy neutrons and results in a higher neutron count rate at the detector.

Total water content in a saturated formation is controlled by the clay content, because clay minerals contain a significant volume of bound water. In view of the inverse relationship described above this means that lower neutron count rates are associated with higher clay content. Repeatability and stability of the neutron tool is routinely checked by measuring the neutron count rate in a barrel of water or federally regulated radioactive pits. No quantitative calibration is performed since the neutron log is a qualitative, relative measurement.

2.9 Heat Pulse Flowmeter

The Heat Pulse Flowmeter, manufactured by Mount Sopris Instruments, is a high resolution device for measuring vertical fluid movement within the borehole. This flowmeter is based upon the proven USGS design and works on the thermal fluid tracer concept. Borehole fluid is heated or thermally tagged by as much as 1° F with an electrical heater grid. The flow rate is determined by measuring the time between the grid discharge and the peak of the thermal pulse of water reaching an upper or lower thermistor sensor. In larger wells, the flowmeter utilizes flow concentrating diverters to direct fluid flowing in the borehole through the probe flow tube (Figure 1).

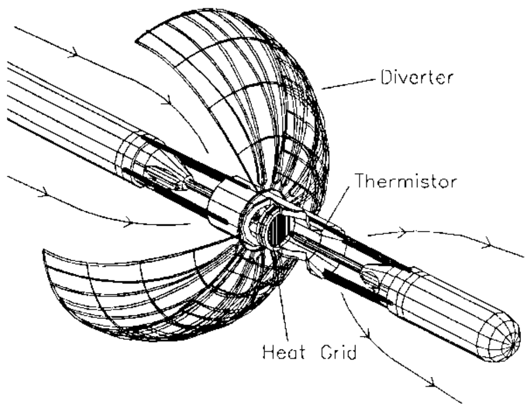


Figure: Heat pulse flowmeter diverter diagram showing fluid flow

The Heat Pulse Flowmeter was calibrated in a flow chamber, at Mount Sopris Instruments, where flow rate can be controlled and measured. Values for response time were taken for 0.03 and 1.00 gallons/minute upflow, and for 0.03 and 1.00 gallons/minute downflow. As compared to the empirical curve-fit solution (Figure 2), these calibration points provide only a linear conversion from time to flow rate. The empirical curve is nearly linear, within this region. The probe provides measurable temperature peaks, with accurate calculated rates, from about 0.016 gallons/minute to about 1.2 gallons/minute. Flow rate values indicated outside this range are essentially an educated guess by the operator, in the field.

Flow is measured at each interval and each test repeated until at least three measurements are recorded within given tolerances. While the actual time to record a flow rate of 0.016 gpm is less than 30 seconds, it may take up to 15 minutes per station for the borehole to stabilize and to obtain repeatable data. At higher flow rates, the borehole stabilizes more quickly and obtaining good data may take only a few minutes per station.

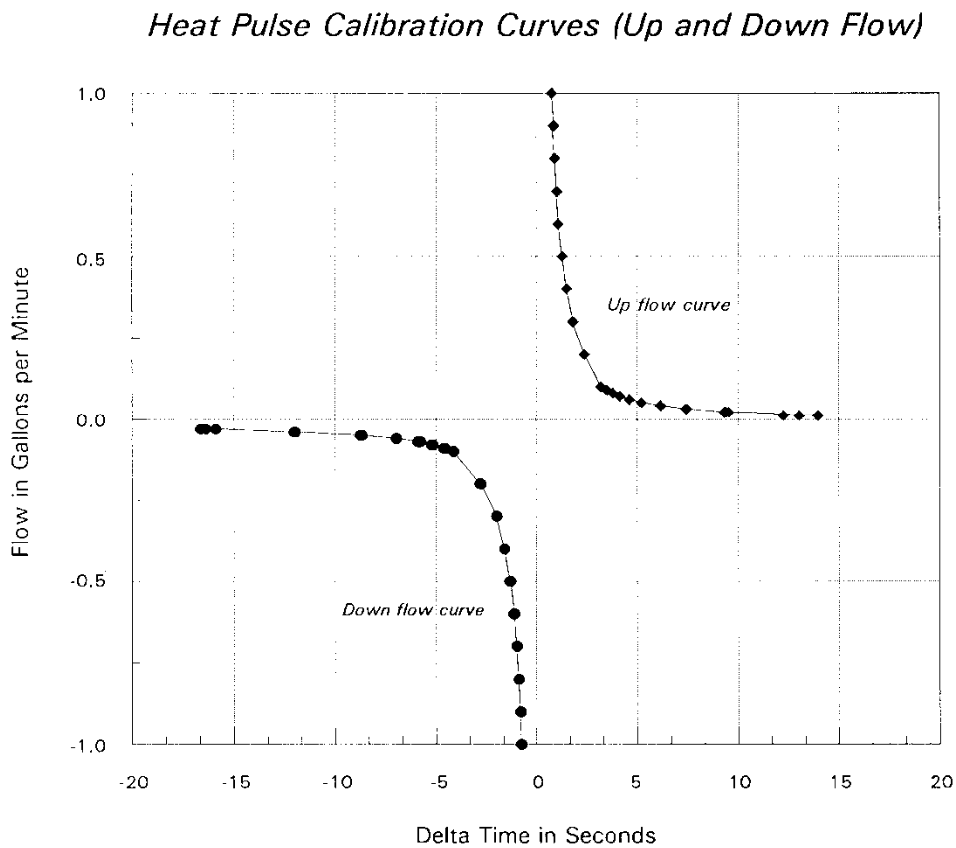


Figure 2: Heat pulse flowmeter calibration curves used to translate response time to gpm.

A number of factors must be considered when interpreting high-resolution flow data including: 1) the effect of the open borehole on the flow regime in the vicinity of the well bore; 2) the effects of turbulent thermal convection and other secondary flow circulations; 3) real flow regimes are often changing with time as measurements are being made; 4) not all permeable intervals may be producing vertical flow under ambient conditions; and, 5) there is most likely vertical flow through the annulus space, outside the PVC casing, that cannot be diverted through the flowmeter aperture, and therefore cannot be measured by this method.

2.10 Impeller Flowmeter

Impeller Flowmeter logging was performed with a Robertson Geologging High-resolution Impeller Flowmeter.

The spinner, or impeller-type, flow meter consists of impeller blades fixed on a freely rotating shaft at the bottom of the probe. The impeller blades are enclosed in a steel logging cage for protection yet the logging cage still allows for water to move freely by the impeller blades. The flow meter is sensitive to changes in the velocity of the flowing water by the blades by the increased or decreased rate of revolution of the turning blades. The larger the difference between the logging speed of the probe and the velocity of the water moving in the wellbore, the faster the rate of revolution of the impeller blades. Standard procedure is to log at a constant speed up and/or down the well under stressed and non-stressed conditions. The goal is to find the proper logging speed and direction under the specific testing conditions to produce repeatable logs. The different logging speeds and directions used allow the impeller to overcome conditions associated with friction and to measure small flow changes.

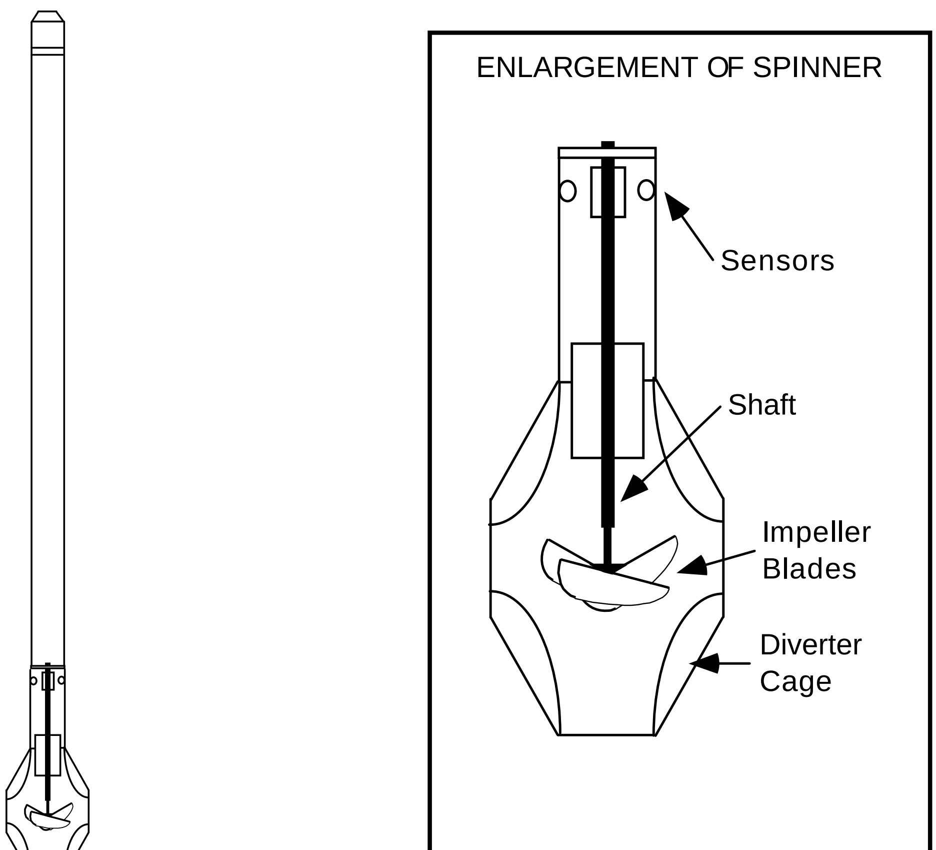


Figure 1: Schematic of the Spinner Flow Meter

Limitations of the spinner flow meter:

- The spinner flow meter has a lower detection limit of approximately 5 vertical feet per minute in a 6" borehole. This is the minimum velocity the wellbore fluids must be moving at in order for the spinner flow meter to detect the rate. This roughly corresponds to 8 gallons per minute.

- Debris in the wellbore fluid column such as bio-material or scaling may hinder the free movement of the impeller blades.

- When possible the spinner flow meter should be centralized. In some cases where a tool-access pipe is used to get the probe by an existing pump in the wellbore centralization is not possible. This does not negate the results of the spinner flow meter, but instead, make repeatable logs more difficult.

3.0 Logging Results

3.1 A-14

On September 8-9, 2011 geophysical logging was performed in vertical 6-inch diameter well A-14. Log depths were referenced to top of casing (TOC) and all depths discussed here will be with respect to TOC. Total depth was found to be 202.9 feet.

The following datasets were logged:

- Natural Gamma
- SP/SPR/Resistivity
- Temp/Fluid Resistivity
- 3-Arm Caliper
- Compensated Density
- Thermal Neutron
- Full-Waveform Sonic
- Heat-Pulse Flowmeter
- Spinner Flowmeter

Water level is registered at approximately 53.3 feet by a pronounced drop in counts per second on the neutron logs and the emergence of usable fluid conductivity. Top of steel casing is most clearly seen on the optical televiewer log at 60.8 feet. Logged density, neutron and natural gamma data above the bottom of casing respond to formation properties behind casing, but will show an offset from open hole values. Logs in steel casing also reflect properties of the casing itself, such as diameter changes at collars.

The most prominent feature across all data sets is the boundary between the basalt above and sediments below 146.5 feet. Neutron counts drop due to an increase in formation water. Density drops significantly in the soft sediments. Increases in caliper readings indicate borehole washout of soft sediments. Caliper inflections in the basalt formation correspond well to fractures seen in the optical televiewer log.

P and S wave formation velocity was derived from an analysis of the full-waveform sonic data. In fractured regions of the basalt formation, the P and S wave velocities are lower than in the non-fractured bulk formation. More-fractured regions appear on the full-waveform sonic plot as lack of vertical coherence of arrival times, or lack of a “clean” wave arrival; these regions correspond well to caliper inflections and fractures seen on the televiewer plot, particularly at depths of 72.7 feet, 80.0 feet and 90.0 feet, for example. P wave velocity drops significantly below a depth of 146.5 feet at the boundary between basalt and sediments.

The formation velocity is so low in the sediments that S wave energy was unable to be determined with this sonic tool; velocities below the compressional velocity of the borehole fluid require different logging techniques to determine.

Flow under ambient and stressed (pumping) conditions was logged in this well. The heat pulse flow meter can register flow rates between approximately 0.01-1.2 gpm, but is only calibrated for flows between 0.03 – 1.0 gpm. The impeller flow meter can measure flows above 8 gallons per minute up to 3000 gallons per minute when at rest. However, sensitivity of the impeller flow meter can be increased by trolling the tool up and down the borehole; the movement of the tool with respect to the borehole fluid allows for determination of flow values below the lower limit of the tool when at rest.

The heat pulse flow meter was used to measure flow under ambient conditions because the flow was within its detections range. Under an average pumping condition of 26.4 gpm, both tools were used to measure flow. Ambient flow results were recorded at discreet locations as necessary to characterize the flow.

Under ambient conditions, there is nominally no flow above 85 feet. Flow of approximately 0.19 gpm is entering the borehole between 85 feet and 96 feet and moving downwards. Additional flow of approximately 0.62 gpm enters the borehole between depths of 86 feet and 113 feet and moves downwards. The aggregate downward flow of approximately 0.80 gpm then continues down the well. Approximately 0.7 gpm exits the borehole below 145 feet and above 151 feet, strongly suggesting most water exits the borehole at the interface between the basalt and sediments under ambient conditions. The remaining 0.1 gpm continues down the borehole and exits between depths of 151 feet and 187 feet, likely via the nearly-vertical fracture that extends from 152 feet to 180 feet. This fracture is highly visible on the televiewer plot.

The well was stressed by placing a pump at 62 feet just below water level. Average maximum pumping rate was 26.4 gpm during the impeller flow meter measurements and 25.9 gpm during the heat pulse flow meter testing. For final flow zone calculations, this small difference in pump rates was ignored and a pumping rate of 26.4 gpm was used. Flow measurements could not be logged above 70.8 feet due to the probe approaching the fixed pump, therefore pumping flow results assume 26.4 gpm upwards flow rate at 70.8 feet; no information on flow is determined above this depth.

Heat pulse flow meter data logged under pumping conditions indicates flow of approximately 0.10 gpm entering the borehole near the bottom of the hole, below 194 feet, and addition flow of approximately 0.07 gpm entering the hole between depths of 152 feet and 180 feet, likely via the near-vertical fracture mentioned in the previous paragraph. Above 117 feet, flow rates were too high to measure with the heat pulse flow meter, indicating large amounts of inflow above 117 feet. This is confirmed by the impeller flow meter data, discussed in the following paragraph.

The impeller flow data logged at a downward trolling speed of 60 ft/min were used to calculate flow results. This data was repeatable and matched the character of other logs ran at 30 ft/min and 90 ft/min, indicating repeatability and valid data. Average RPM values were taken from the log data where RPMs were, on average, constant with depth, indicating no inflow/outflow. Average maximum RPMs nearest the pump were assigned a flow rate of 26.4 gpm and average minimum RPMs below 115 feet were assigned a value of 0.17 gpm, the total inflow indicated by the heat pulse flow meter below this depth.

Flow zones were then identified by comparing depths at which RPMs were changing to features with aperture on the optical televiewer log. The flow zones and their associated flow are show in the table below. This table and calculations combine the flow results from the heat pulse flow meter with the flow information from the impeller flow meter.

Analysis of fracture and feature orientations observed in the optical televiewer log can be found in the appendix along with all data plots.

Flow Zone	Depths of	Average	Change in	Inflow	Inflow

	Inflow	**RPM**	**RPM**	**(%)**	**(GPM)**
1	79.8 – 79.4	1183	28	8.5	2.24
2	94.0 – 88.2	1155	61	18.6	4.88
3	100.5 – 96.1	1094	87	26.5	6.96
4	106.5 – 103.3	1007	139	42.4	11.12
5	112.0 – 107.0	868	13	4.0	1.04
6*	152.0 – 180.0	855		< 0.1	0.07
7*	Below 194			< 0.1	0.10
TOTALS			328	100	**26.4**

* Zones identified from heat pulse flow meter measurements

3.2 A-15

On September 9-10, 2011 geophysical logging was performed in vertical 6-inch diameter well A-15. Log depths were referenced to top of casing (TOC) and all depths discussed here will be with respect to TOC. Total depth was found to be 152.3 feet.

The following datasets were logged:

- Natural Gamma
- Temp/Fluid Resistivity
- 3-Arm Caliper
- Compensated Density
- Thermal Neutron

Water level is registered at approximately 54.4 feet by a pronounced drop in counts per second on the neutron logs and the emergence of usable fluid conductivity. Top of steel casing is most clearly seen on the caliper log at 58.1 feet. Logged density, neutron and natural gamma data above the bottom of casing respond to formation properties behind casing, but will show an offset from open hole values. Logs in steel casing also reflect properties of the casing itself, such as diameter changes at collars.

The most prominent feature across all data sets is the presumed boundary between the basalt above and sediments below 145.0 feet. Neutron counts drop due to an increase in formation water. Density drops significantly in the soft sediments. Increases in caliper readings indicate borehole washout of soft sediments. While there is no televiewer log to confirm this interpretation, the data trends in the density and neutron data are similar to those of this boundary in A-14.

Caliper log inflections above 145 feet likely correspond to major fractures in the basalt, similar to those seen in the televiewer log for A-14.

3.3 A-16

On September 8-9, 2011 geophysical logging was performed in vertical 6-inch diameter well A-16. Log depths were referenced to top of casing (TOC) and all depths discussed here will be with respect to TOC. Total depth was found to be 201.7 feet.

The following datasets were logged:

- Natural Gamma
- SP/SPR/Resistivity
- Temp/Fluid Resistivity
- 3-Arm Caliper
- Compensated Density
- Thermal Neutron
- Full-Waveform Sonic
- Heat-Pulse Flowmeter

Water level is registered at approximately 100.8 feet by a pronounced drop in counts per second on the neutron logs and the emergence of usable fluid conductivity readings. Water level can also be seen on the televiewer log. Top of steel casing is most clearly seen on the optical televiewer log at 113.8 feet. Logged density, neutron and natural gamma data above the bottom of casing respond to formation properties behind casing, but will show an offset from open hole values. Logs in steel casing also reflect properties of the casing itself, such as diameter changes at collars.

Increases in caliper readings indicate borehole washout of soft sediments. In general, these caliper inflections correspond to lower density features on the density logs.

P wave formation velocity was derived from an analysis of the full-waveform sonic data. The formation velocity is so low in the sediments that S wave energy was unable to be determined with this sonic tool; velocities below the compressional velocity of the borehole fluid require different logging techniques to determine.

The noise throughout the SP, SPR and normal resistivity logs is likely not due to the formation properties. It could be associated with equipment issues or an outside source of electrical interference. However, the average values of the resistivities match what was seen in the sediments in A-14.

Flow under ambient and stressed (pumping) conditions was logged in this well with the heat pulse flow meter. The heat pulse flow meter can register flow rates between approximately 0.01-1.2 gpm, but is only calibrated for flows between 0.03 – 1.0 gpm. Ambient flow results were recorded at discreet locations as necessary to characterize the flow.

Under ambient conditions, water enters the borehole from 116 feet to 156 feet at several locations and flows downwards at rates below 0.024 gpm. Water exits the borehole between depths of 156 feet and 192 feet. There is no flow detected below 192 feet under ambient conditions.

The well was stressed by placing a pump at 113 feet just below water level. The average pumping rate was 2.5 gpm during the pumping measurements. Heat pulse flow meter data logged under pumping conditions indicates flow of approximately 0.27 gpm entering the borehole near the bottom of the hole, below 192 feet. An additional 0.56 gpm of flow enters the borehole between 178 and 188 feet. There is a non-fracture feature on the televiewer log at a depth of 184.4 feet that is a likely source of inflow. An additional 0.53 gpm of inflow enters the borehole at several places above 178 feet to 113.8 feet , with no particular feature contributing dominantly. There does not appear to be any significant inflow between depths of 131 feet and 148 feet.

Analysis of fracture and feature orientations observed in the optical televiewer log can be found in the appendix along with all data plots.

4.0 Limitations

COLOG's logging was performed in accordance with generally accepted industry practices. COLOG has observed that degree of care and skill generally exercised by others under similar circumstances and conditions. Interpretations of logs or interpretations of test or other data, and any recommendation or hydrogeologic description based upon such interpretations, are opinions based upon inferences from measurements, empirical relationships and assumptions. These inferences and assumptions require engineering judgment, and therefore, are not scientific certainties. As such, other professional engineers or analysts may differ as to their interpretation. Accordingly, COLOG cannot and does not warrant the accuracy, correctness or completeness of any such interpretation, recommendation or hydrogeologic description.

All technical data, evaluations, analysis, reports, and other work products are instruments of COLOG's professional services intended for one-time use on this project. Any reuse of work product by Client for other than the purpose for which they were originally intended will be at Client's sole risk and without liability to COLOG. COLOG makes no warranties, either express or implied. Under no circumstances shall COLOG or its employees be liable for consequential damages.

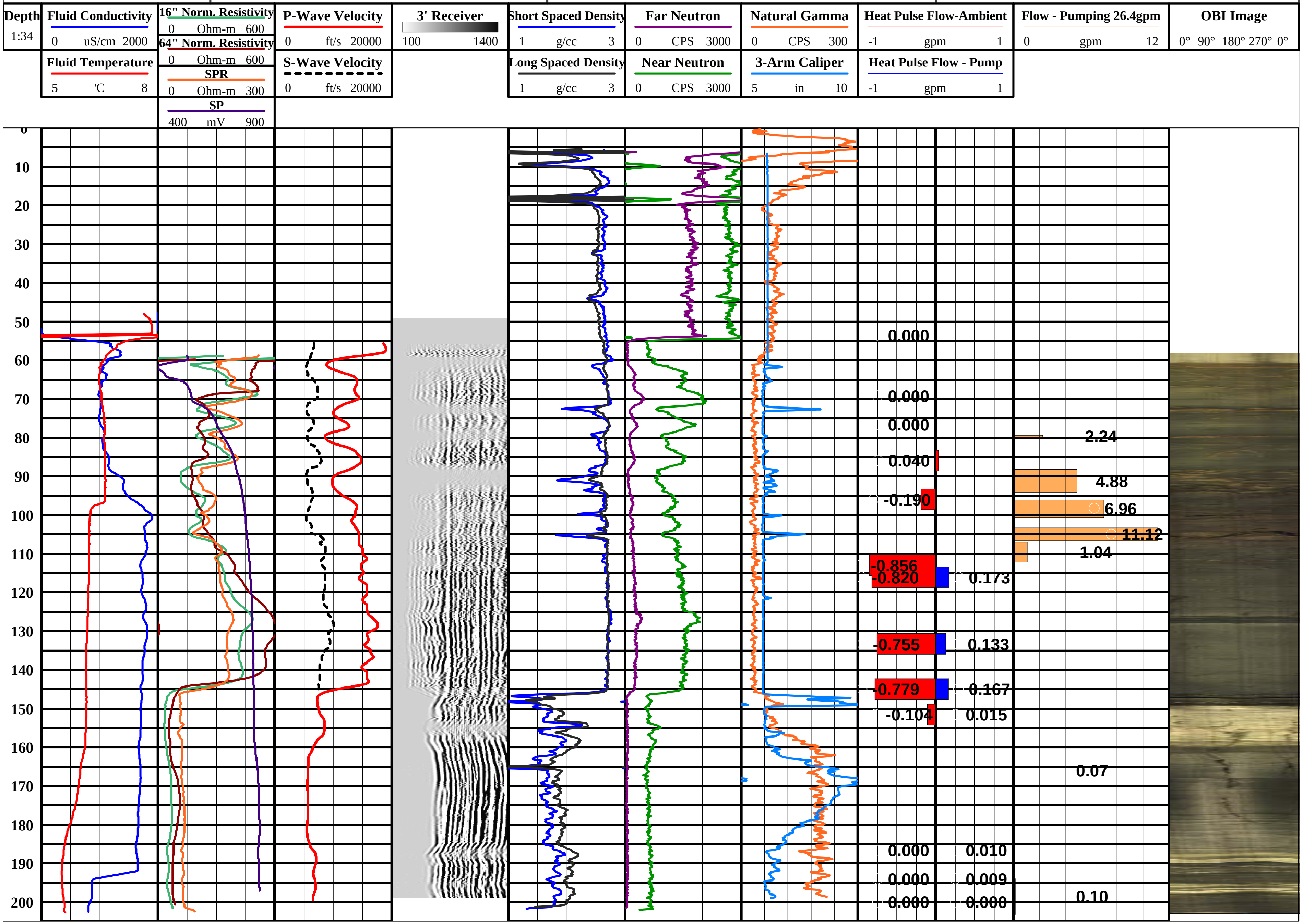
Appendix A
A-14 Geophysical Data

Geophysical/Hydrophysical Summary Plot

COLOG — BOREHOLE GEOPHYSICS & HYDROPHYSICS — A DIVISION OF LAYNE CHRISTENSEN COMPANY

COMPANY: WSP	PROJECT: Nu-West
DATE LOGGED: 8, 9 Sept. 2011	WELL: A-14

COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com



BOREHOLE GEOPHYSICS & HYDROPHYSICS
COLOG
A DIVISION OF LAYNE CHRISTENSEN COMPANY

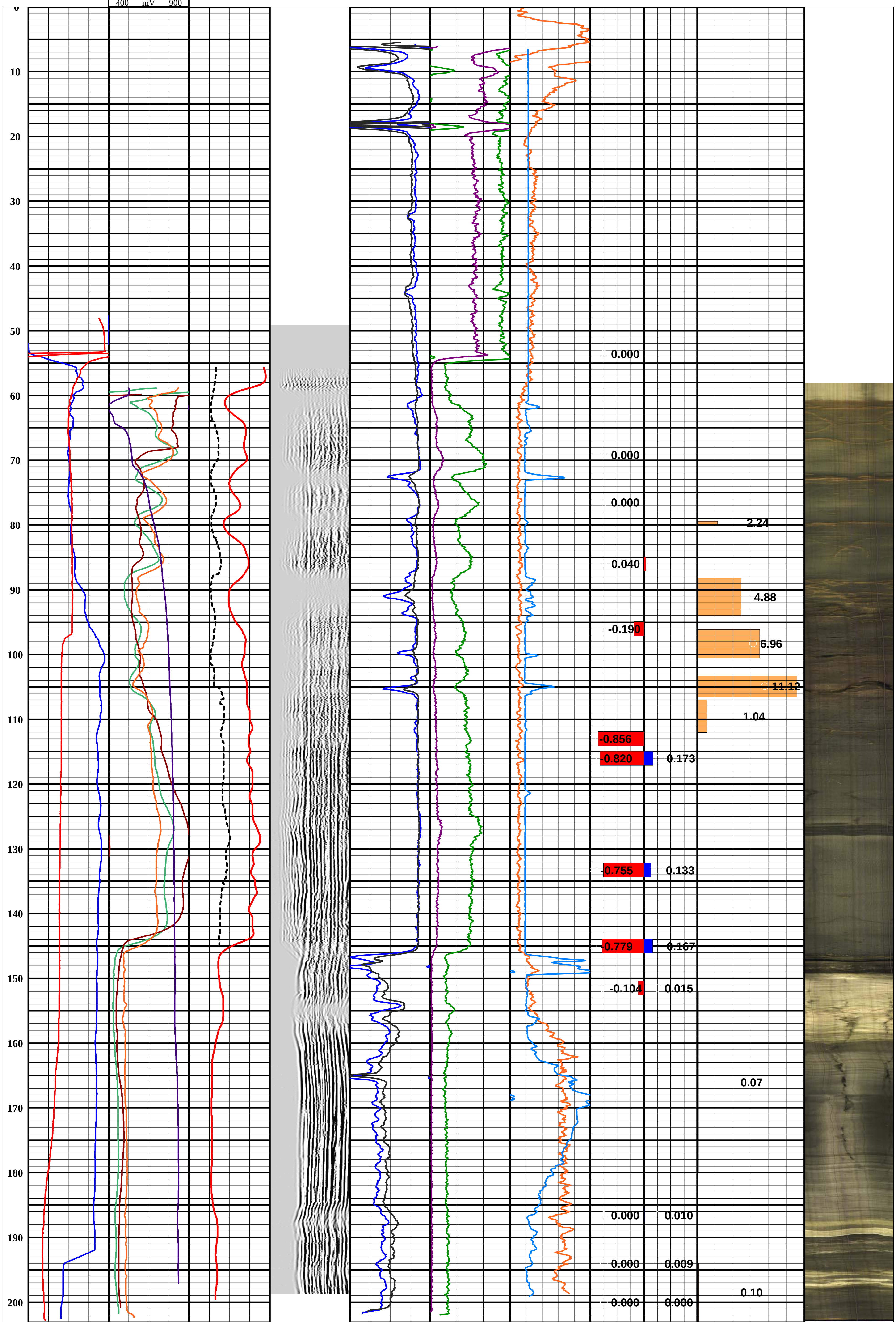
Geophysical/Hydrophysical Summary Plot

COMPANY: **WSP** | PROJECT: **Nu-West**

DATE LOGGED: **8, 9 Sept. 2011** | WELL: **A-14**

COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

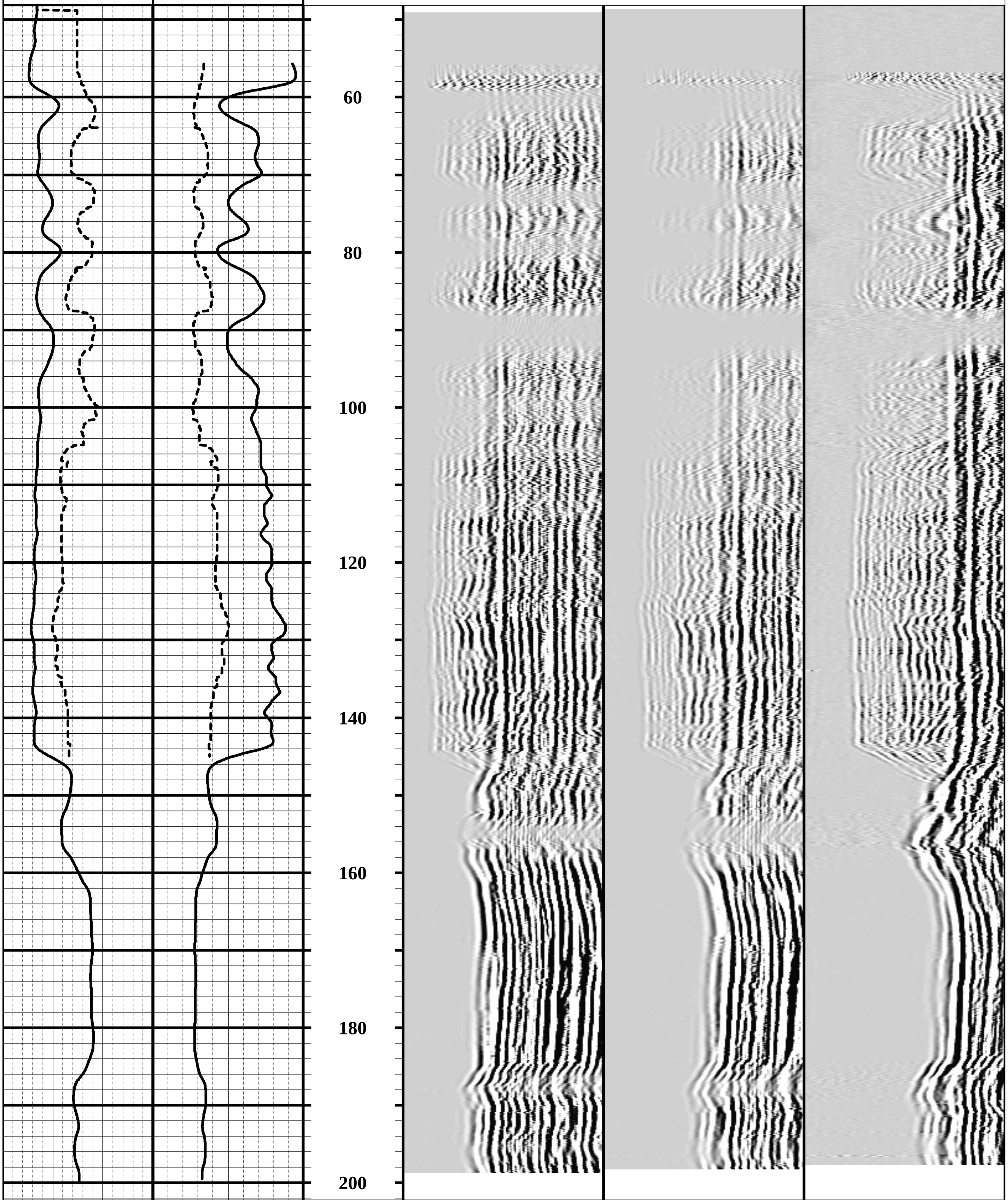
Depth 1:14		
	Fluid Conductivity	0 uS/cm 2000
	Fluid Temperature	5 'C 8
	16" Norm. Resistivity	0 Ohm-m 600
	64" Norm. Resistivity	0 Ohm-m 600
	SPR	0 Ohm-m 300
	SP	400 mV 900
	P-Wave Velocity	0 ft/s 20000
	S-Wave Velocity	0 ft/s 20000
	3' Receiver	100 1400
	Short Spaced Density	1 g/cc 3
	Long Spaced Density	1 g/cc 3
	Far Neutron	0 CPS 3000
	Near Neutron	0 CPS 3000
	Natural Gamma	0 CPS 300
	3-Arm Caliper	5 in 10
	Heat Pulse Flow-Ambient	-1 gpm 1
	Heat Pulse Flow - Pump	-1 gpm 1
	Flow - Pumping 26.4gpm	0 gpm 12
	OBI Image	0° 90° 180° 270° 0°



Full-Waveform Sonic

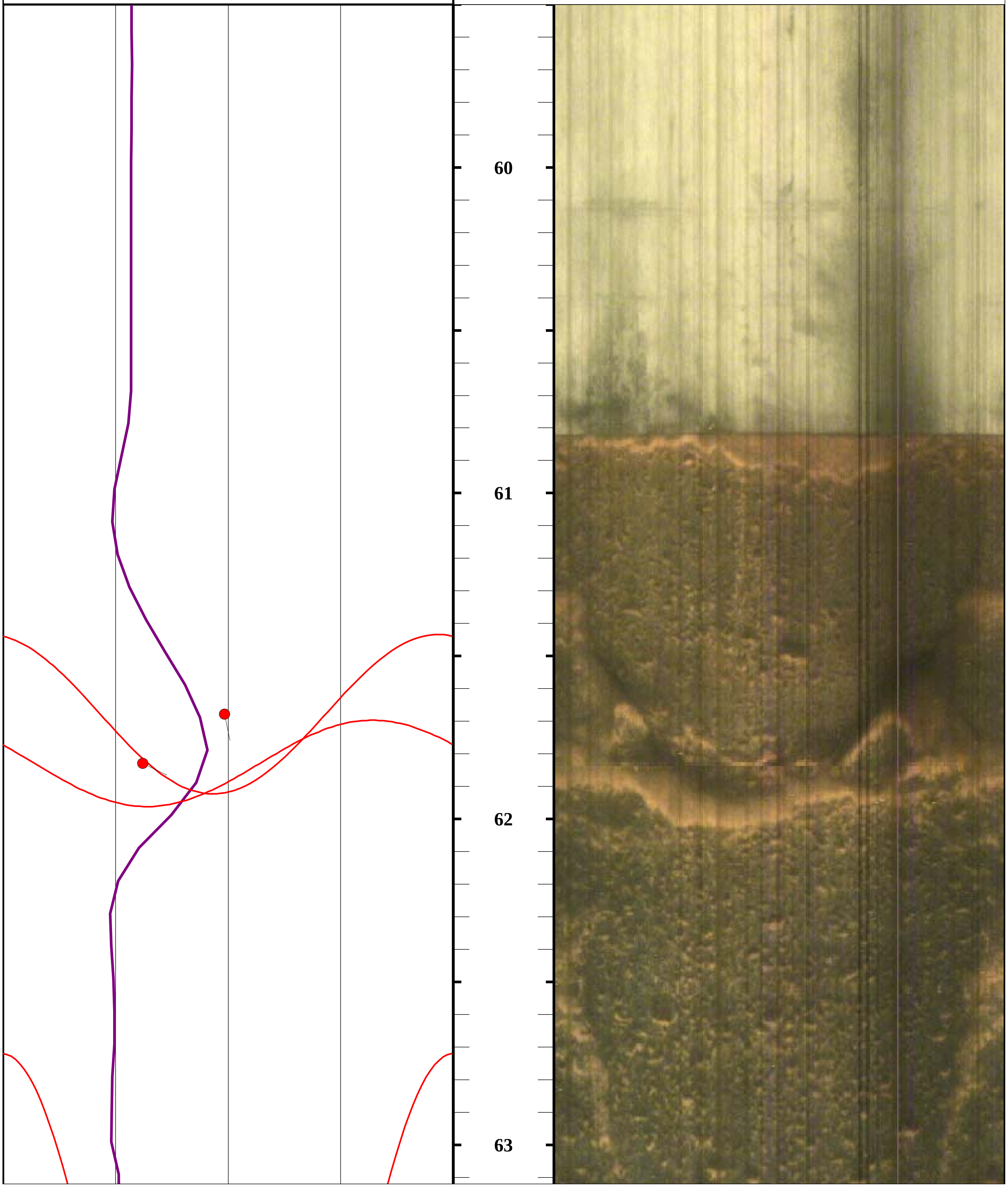
BOREHOLE GEOPHYSICS & HYDROPHYSICS COLOG A DIVISION OF LAYNE CHRISTENSEN COMPANY	COMPANY: WSP	PROJECT: Nu-West	COLOG Main Office 810 Quail Street, Suite E, Lakewood, CO 80215 Phone: (303) 279-0171, Fax: (303) 278-0135 www.colog.com
	DATE LOGGED: 8 Sept. 2011	WELL: A14	

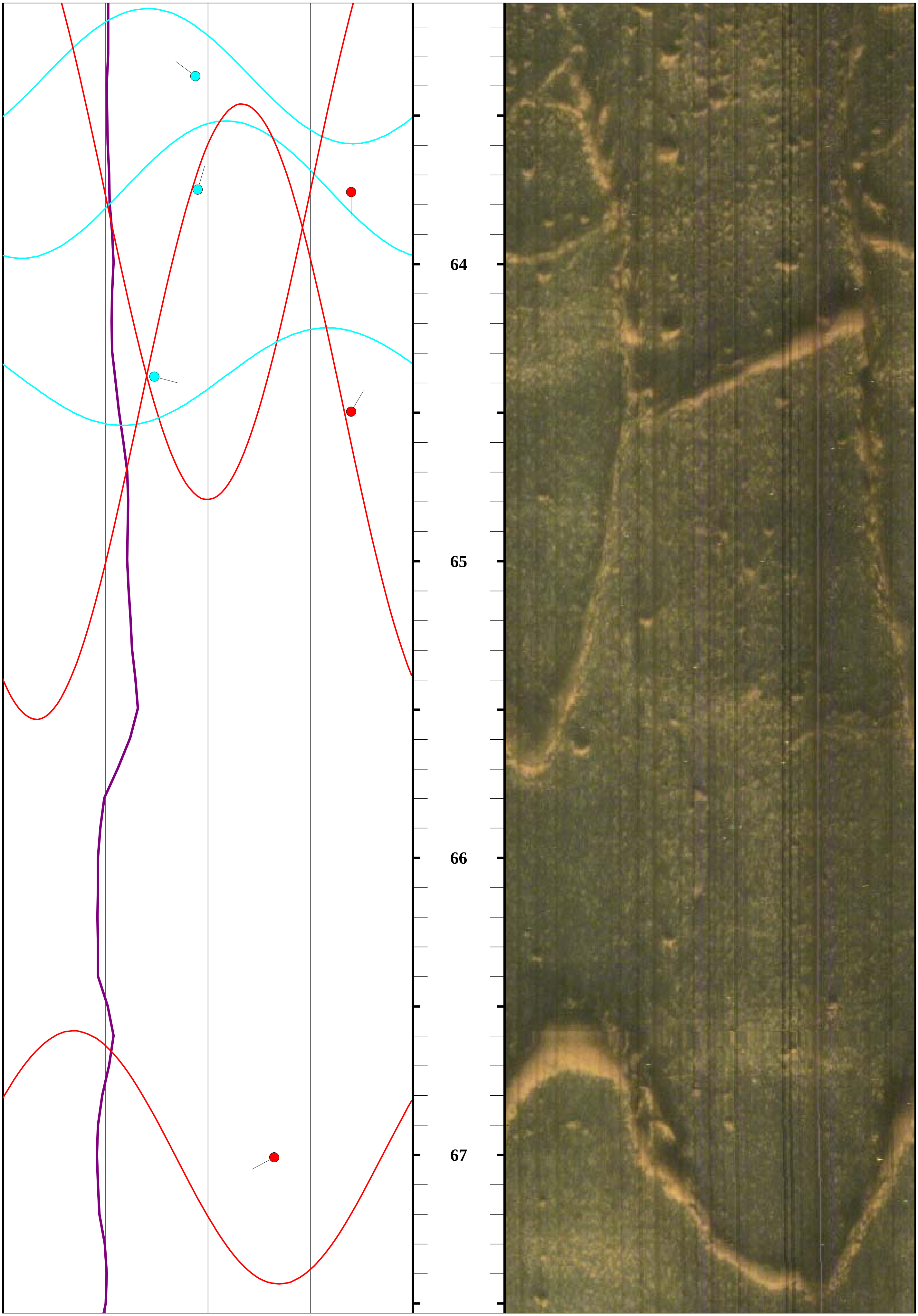
P-Wave Slowness	P-Wave Velocity	Depth	3' Receiver	4' Receiver	5' receiver
0 us/ft 300	0 ft/s 20000	1ft:210ft	100 1400	100 1400	100 1400
S-Wave Slowness	S-Wave Velocity				
0 us/ft 300	0 ft/s 20000				



BOREHOLE GEOPHYSICS & HYDROPHYSICS COLOG A DIVISION OF LAYNE CHRISTENSEN COMPANY	**Optical Televiewer Image Plot**	**COLOG Main Office**
	COMPANY: WSP / **PROJECT: Nu-West CPO**	**810 Quail Street, Suite E, Lakewood, CO 80215**
	DATE LOGGED: 8 Sept 2011 / **WELL: A-14**	**Phone: (303) 279-0171, Fax: (303) 278-0135**
		www.colog.com

3-Arm Caliper	**Depth**	**Optical Image - MN**
5 in 9	1ft:5ft	0° 90° 180° 270° 0°
Projections - MN		
0° 90° 180° 270° 0°		
Tadpoles - MN		
0 90		

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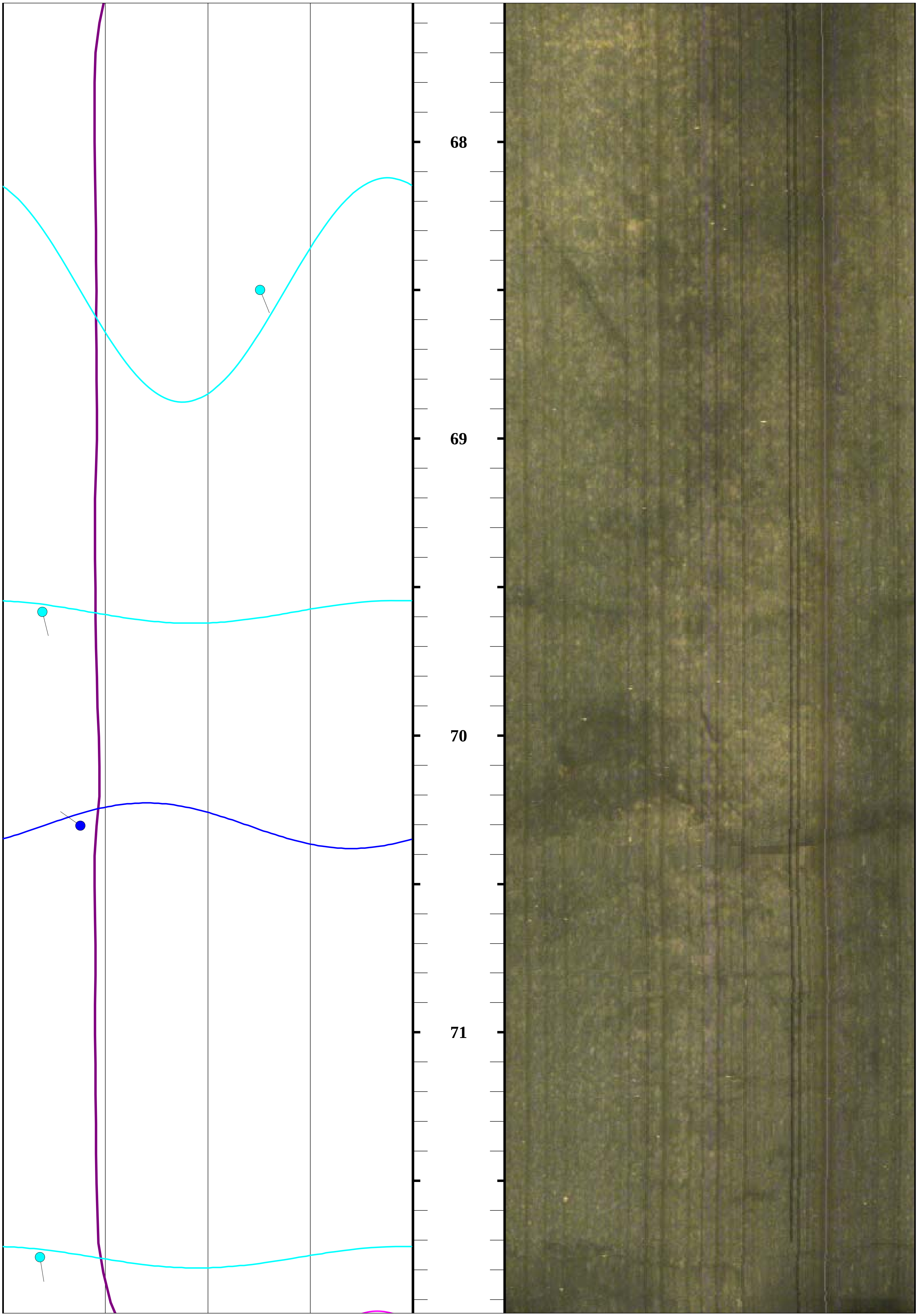
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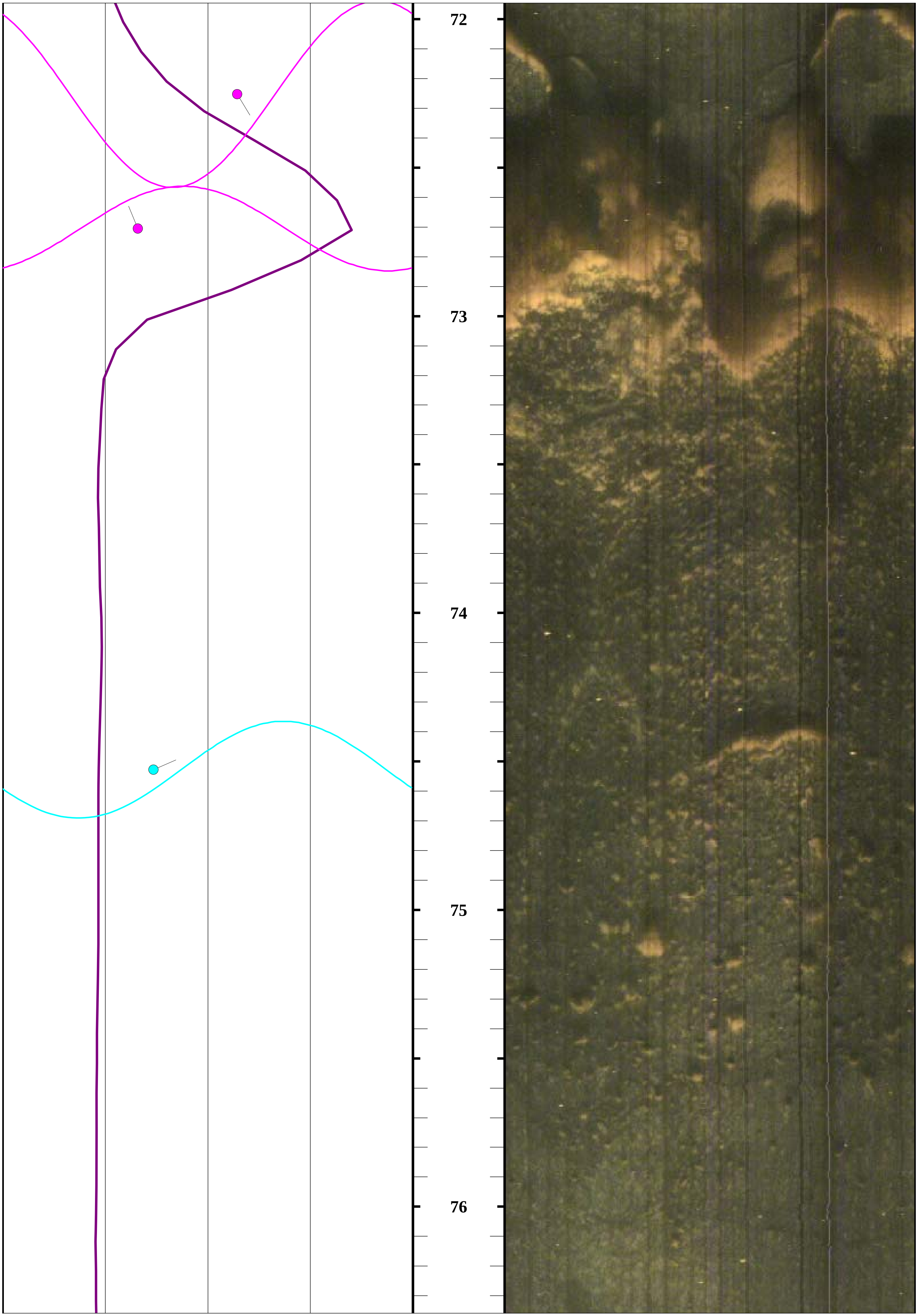

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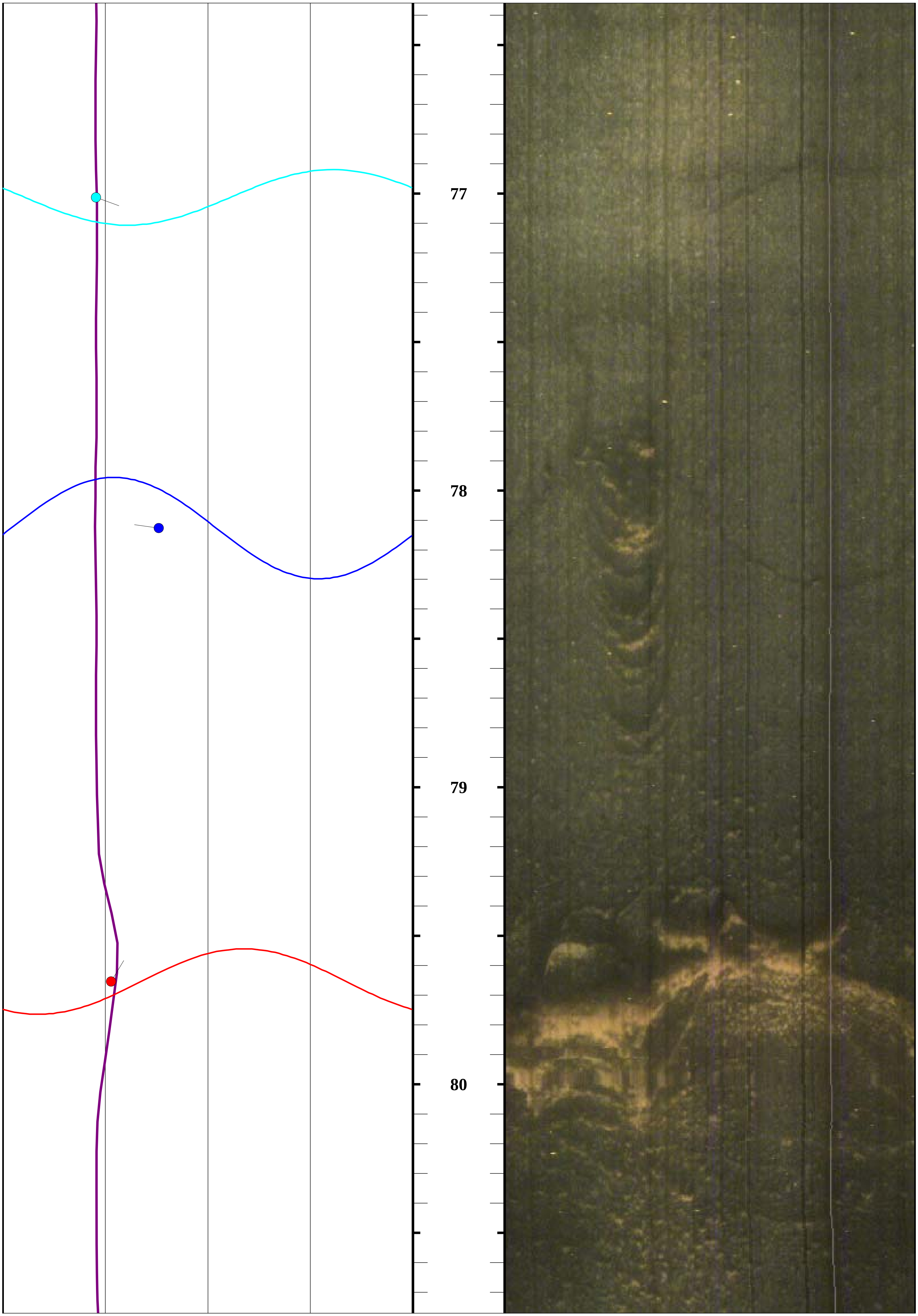
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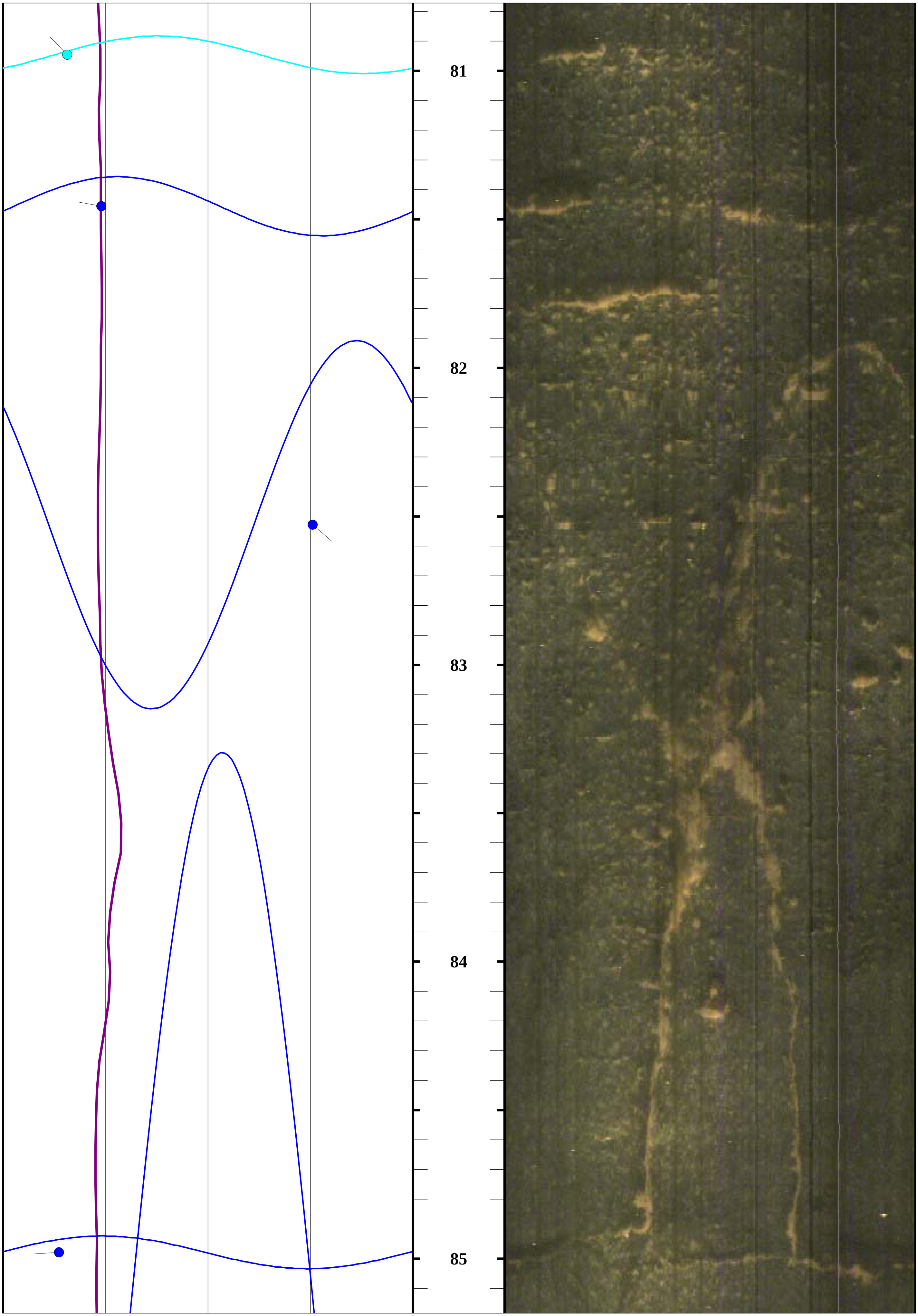
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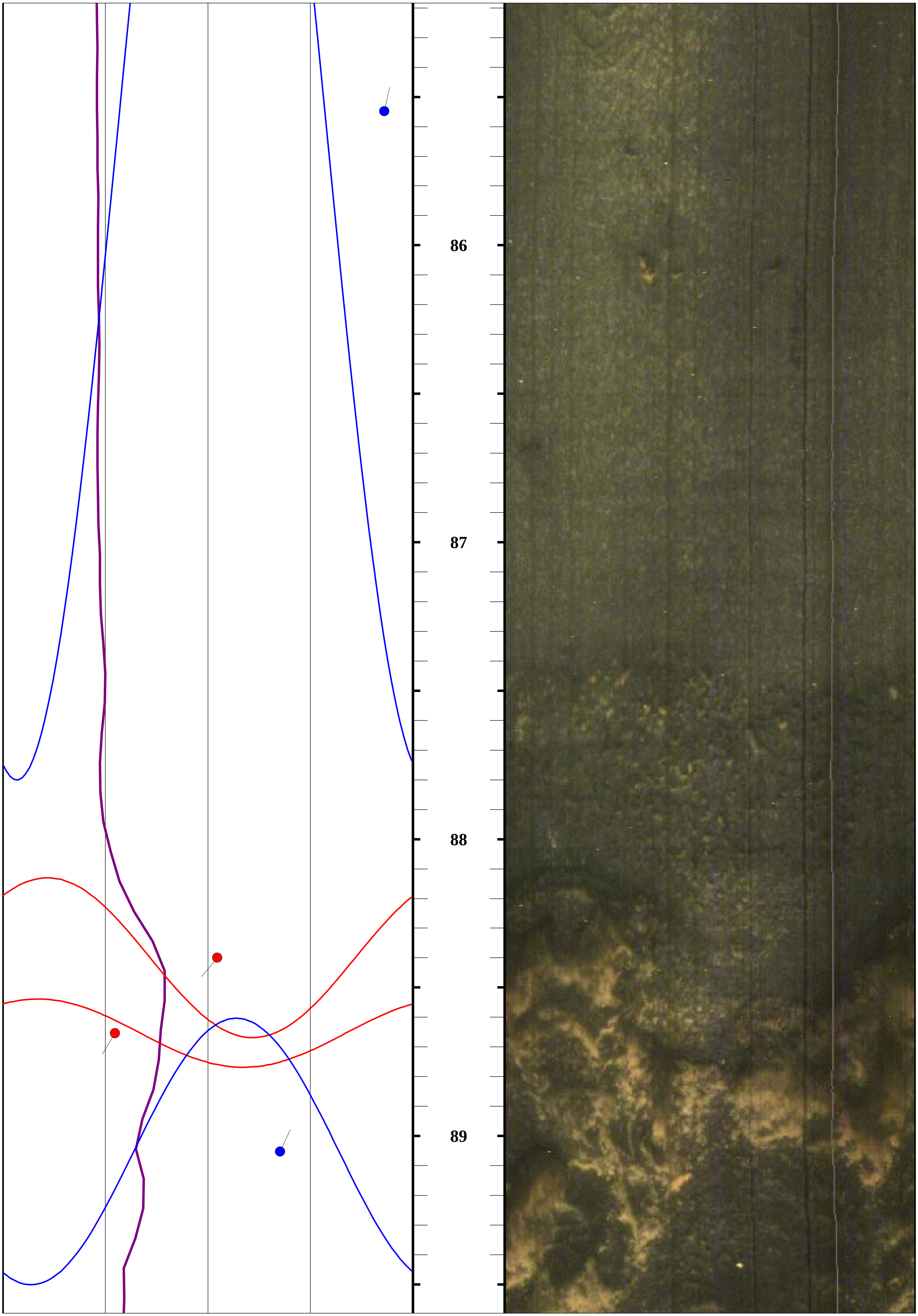
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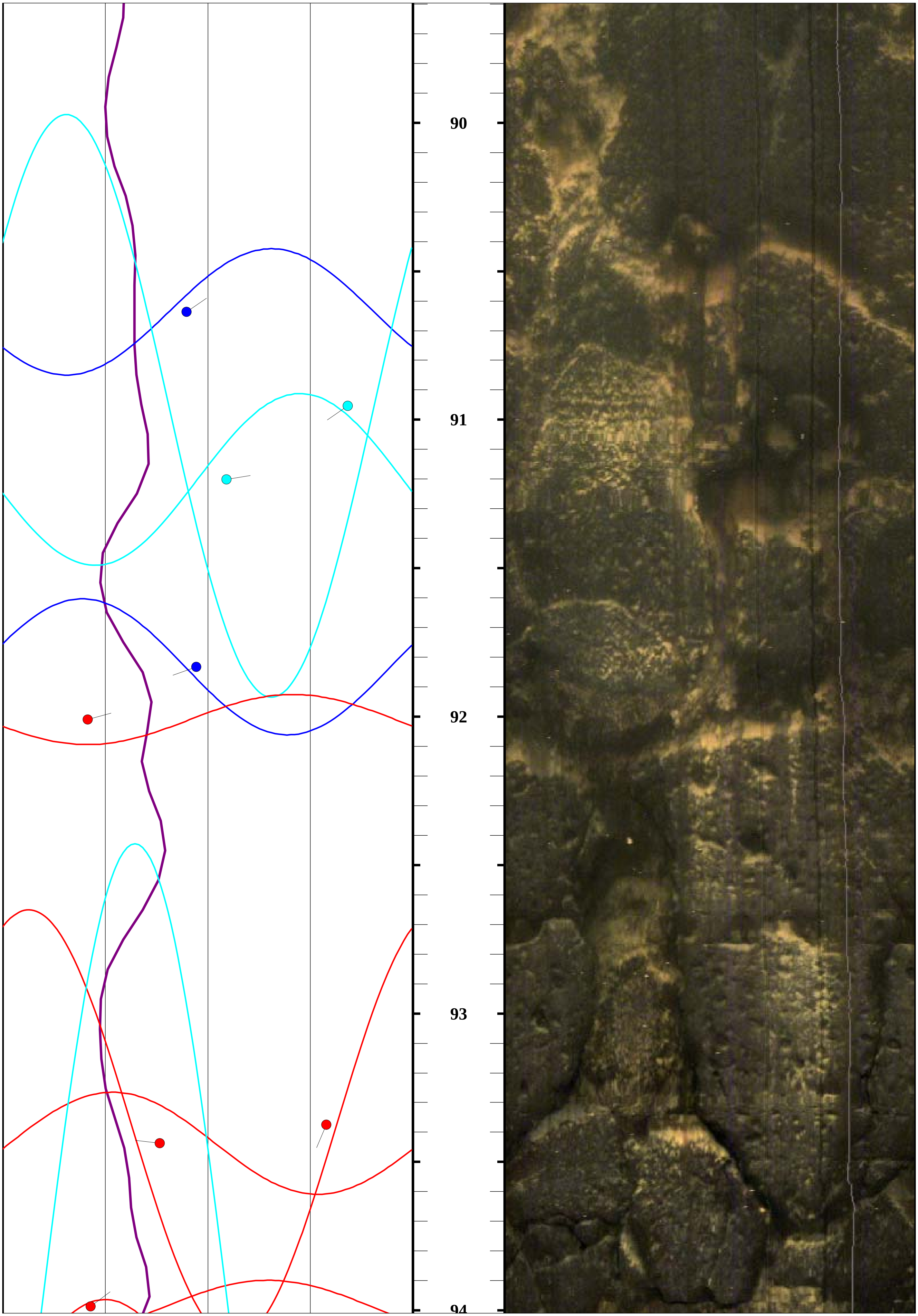
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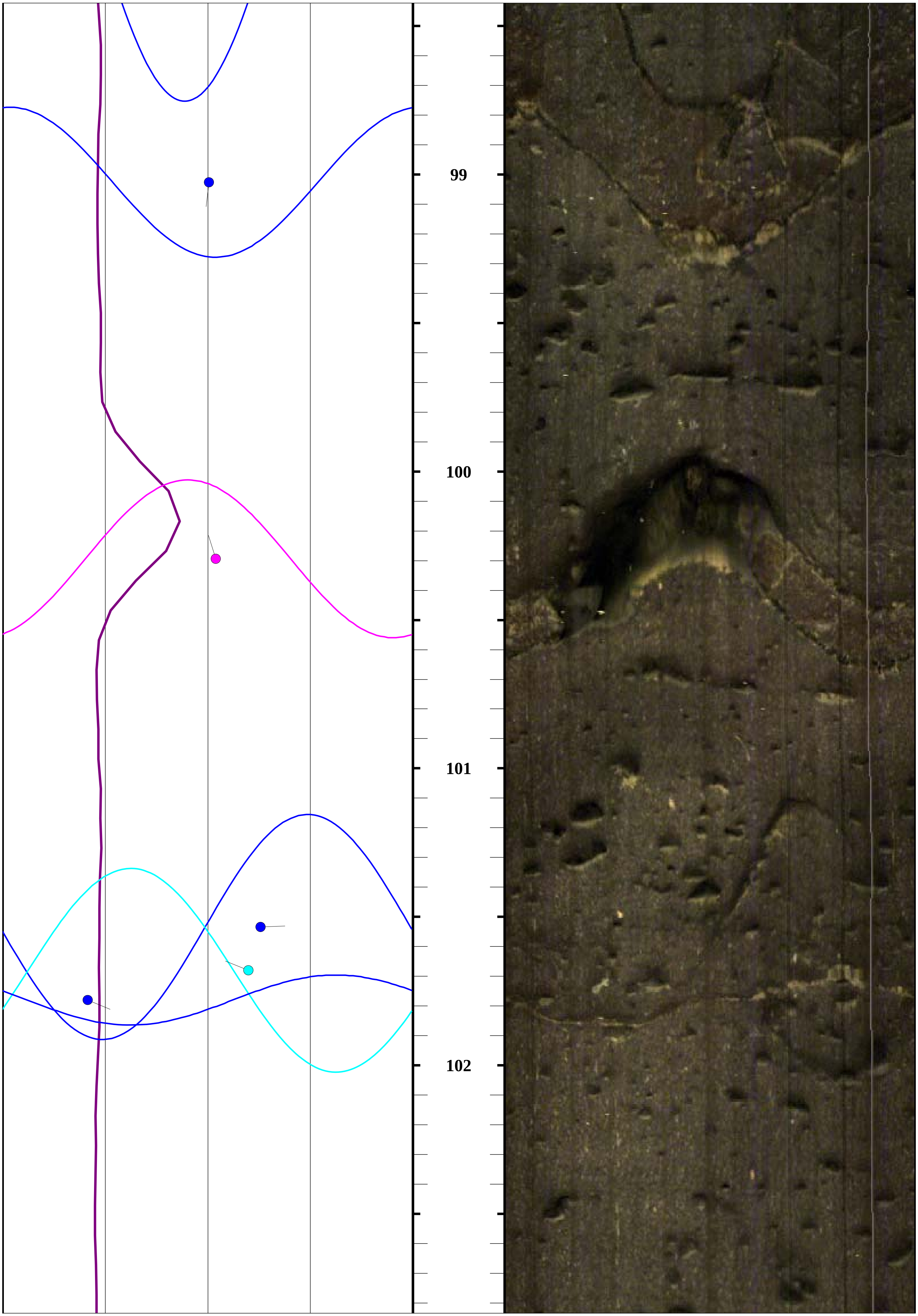
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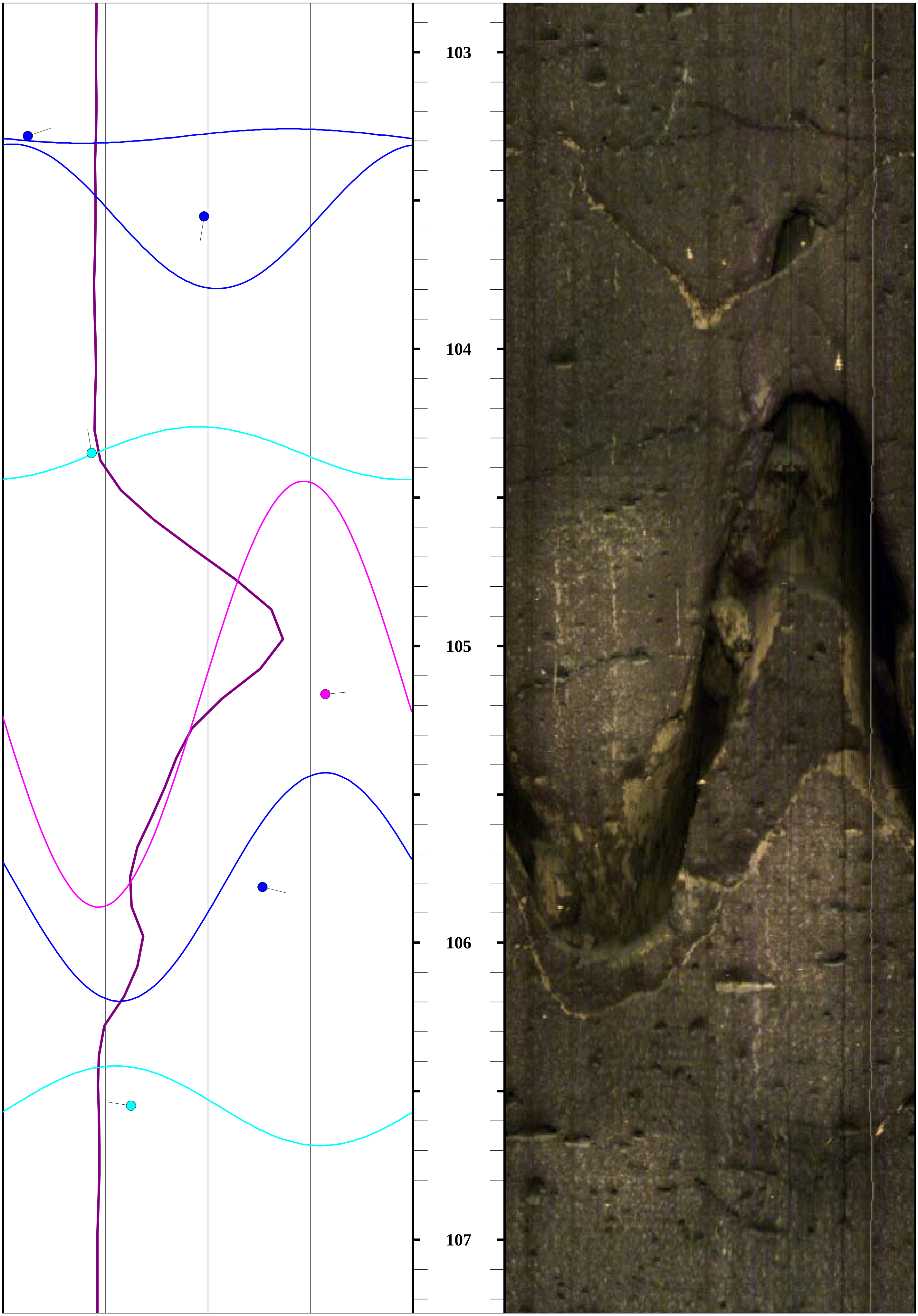
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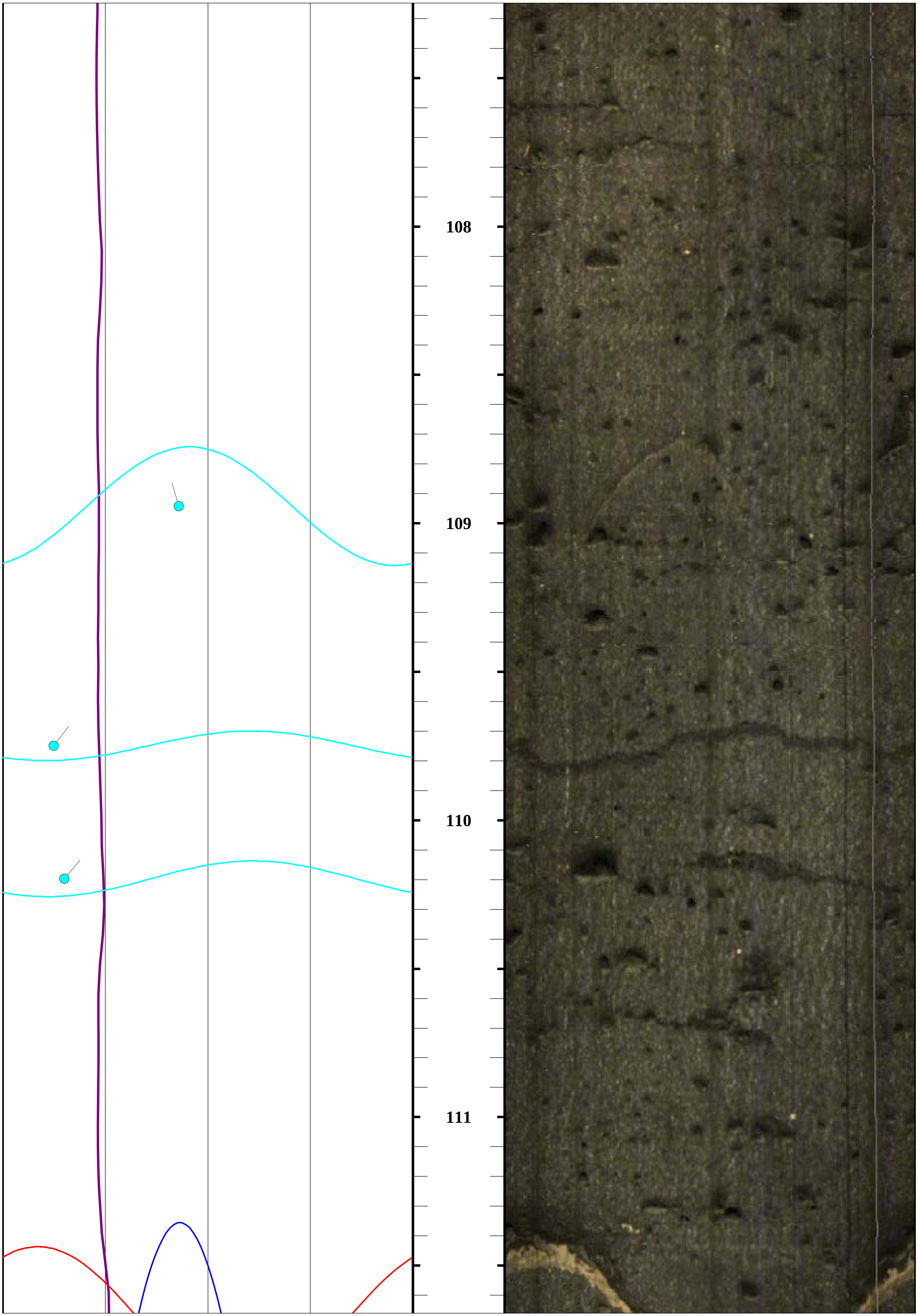

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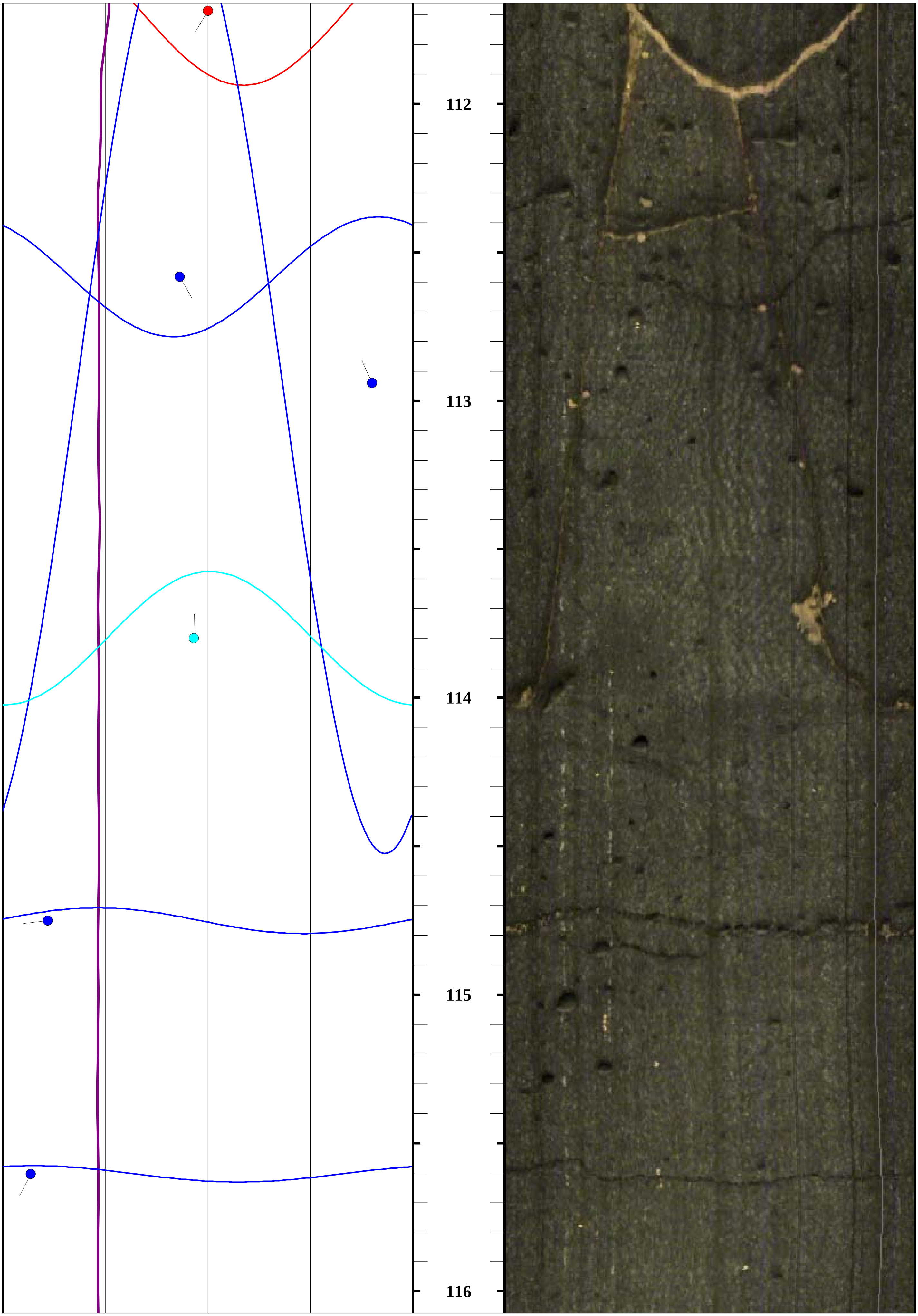
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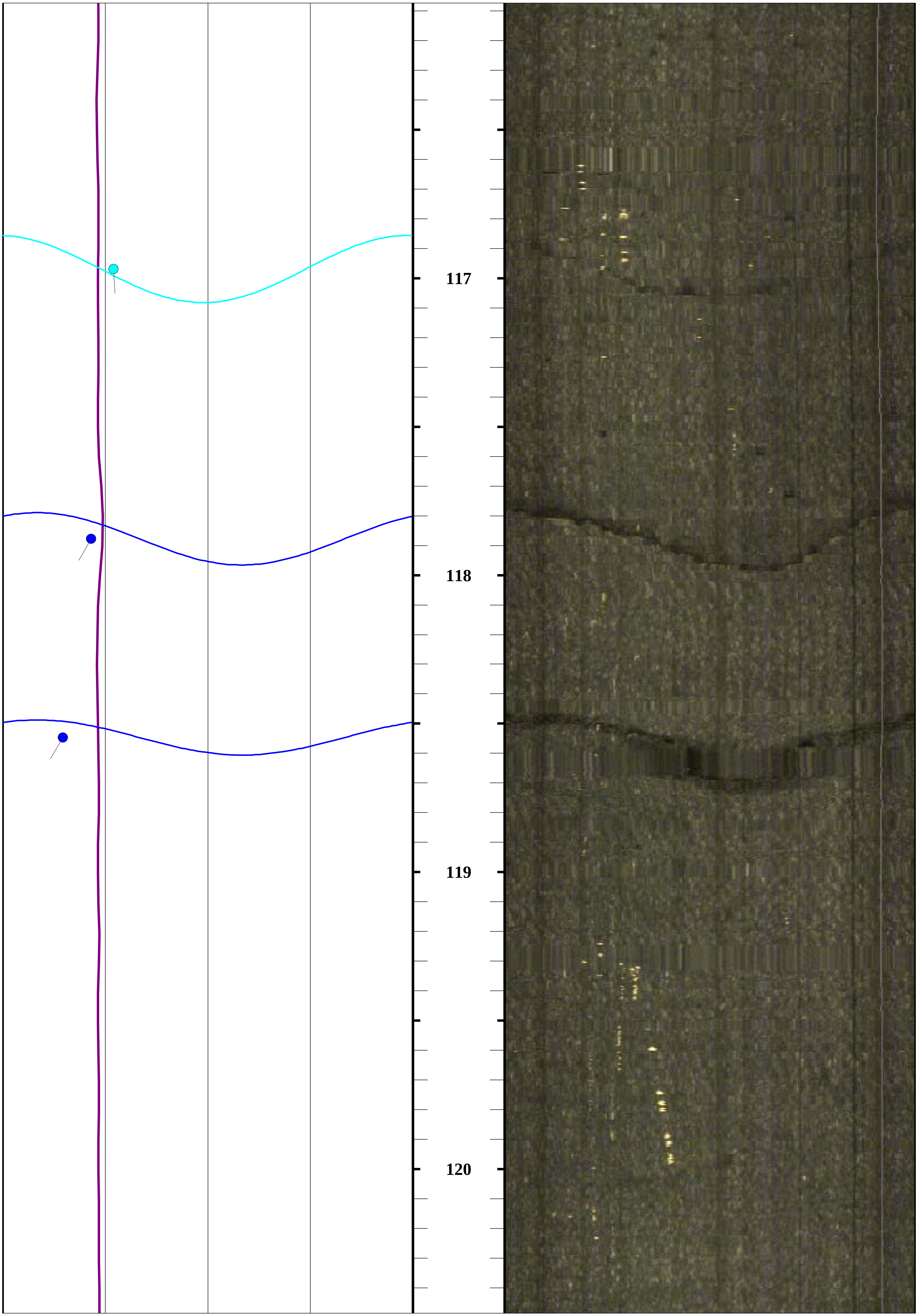
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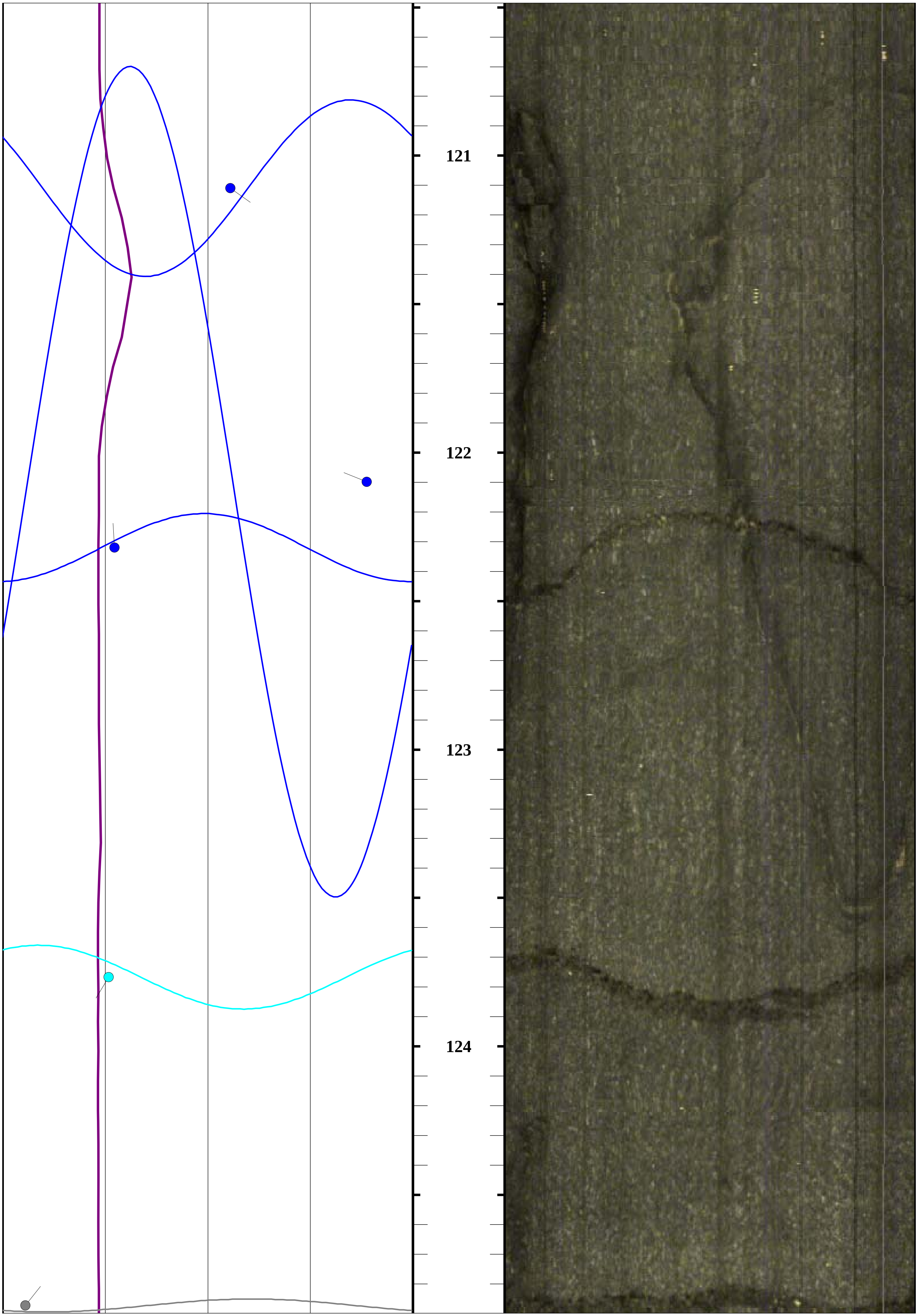
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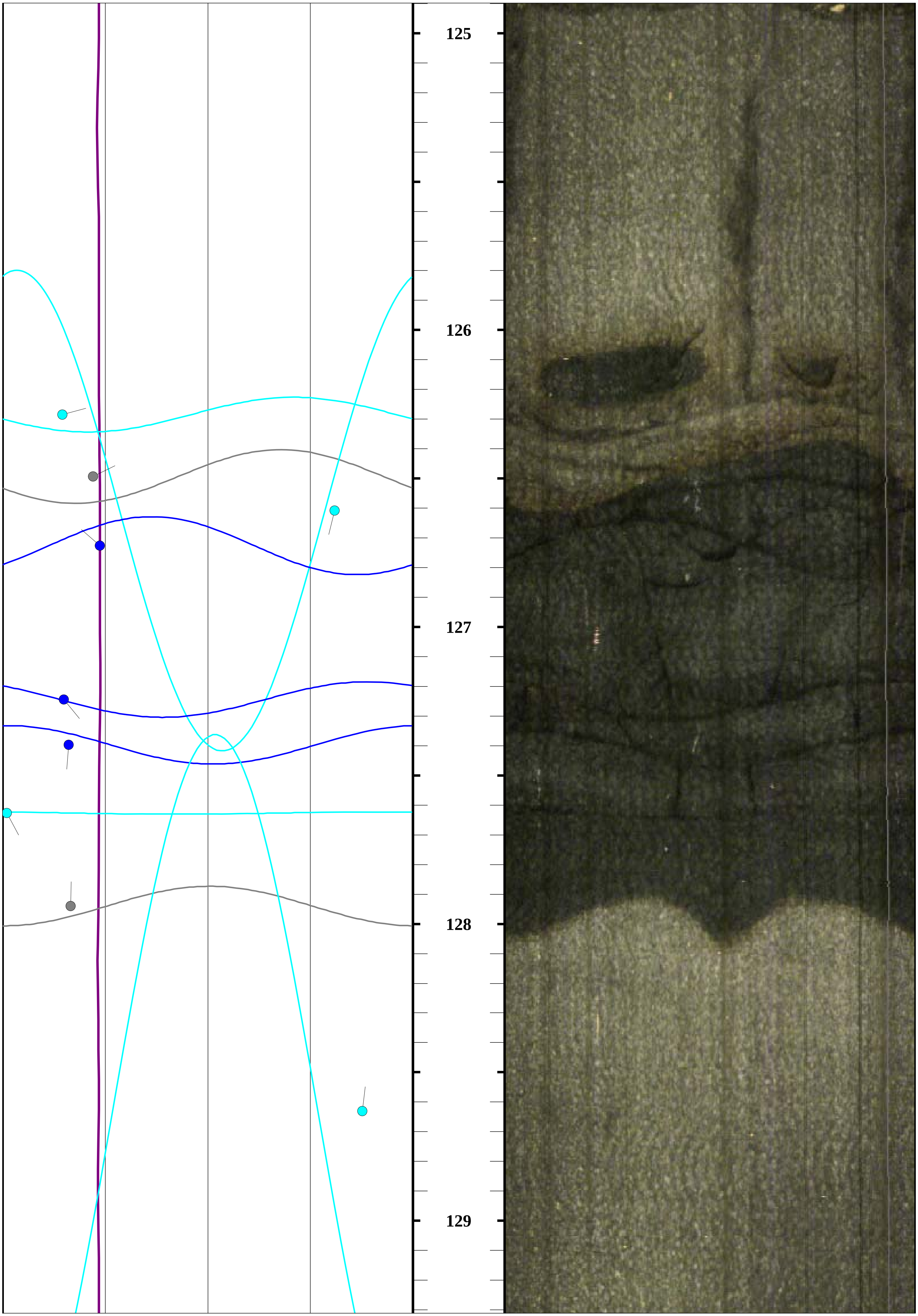
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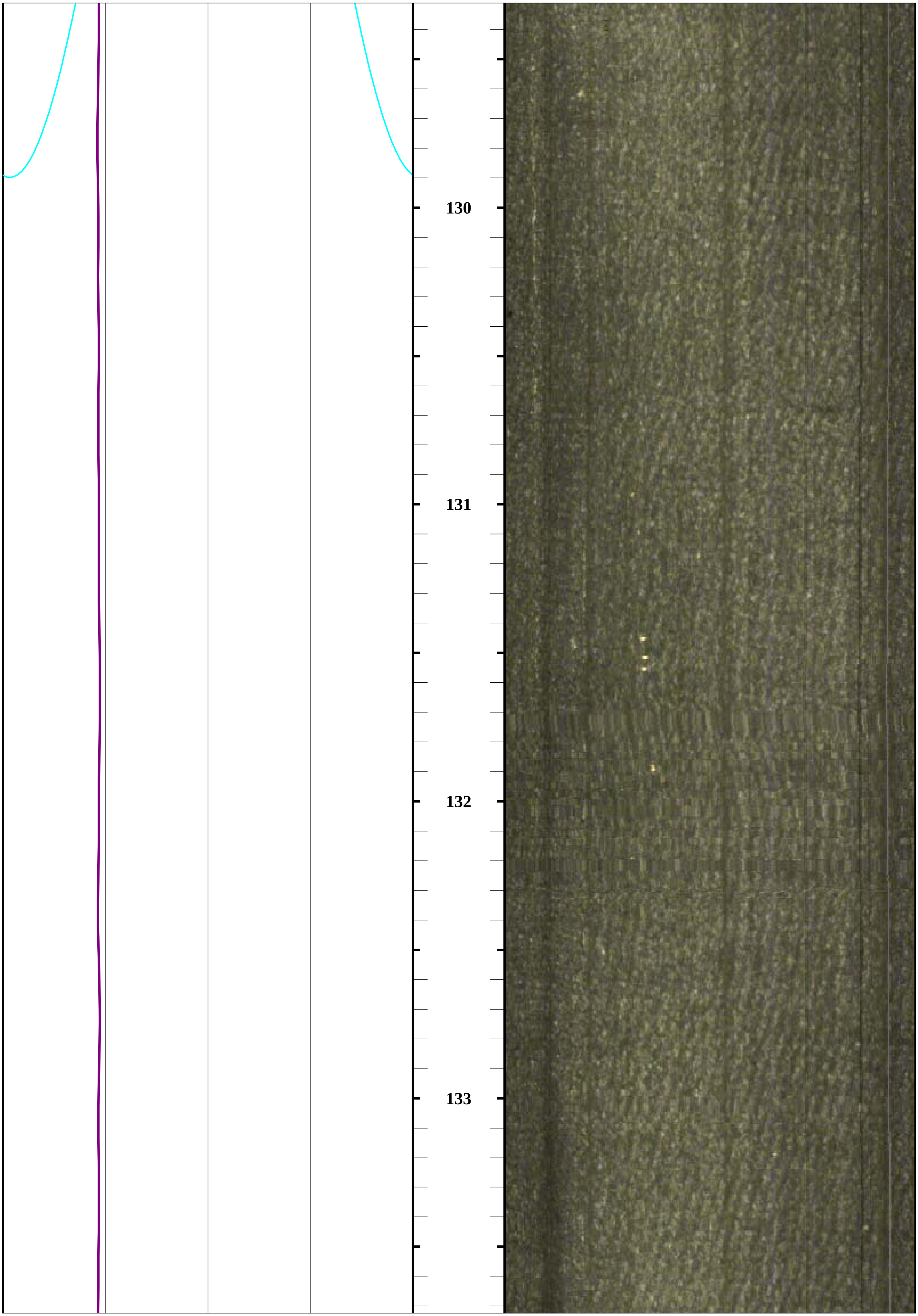
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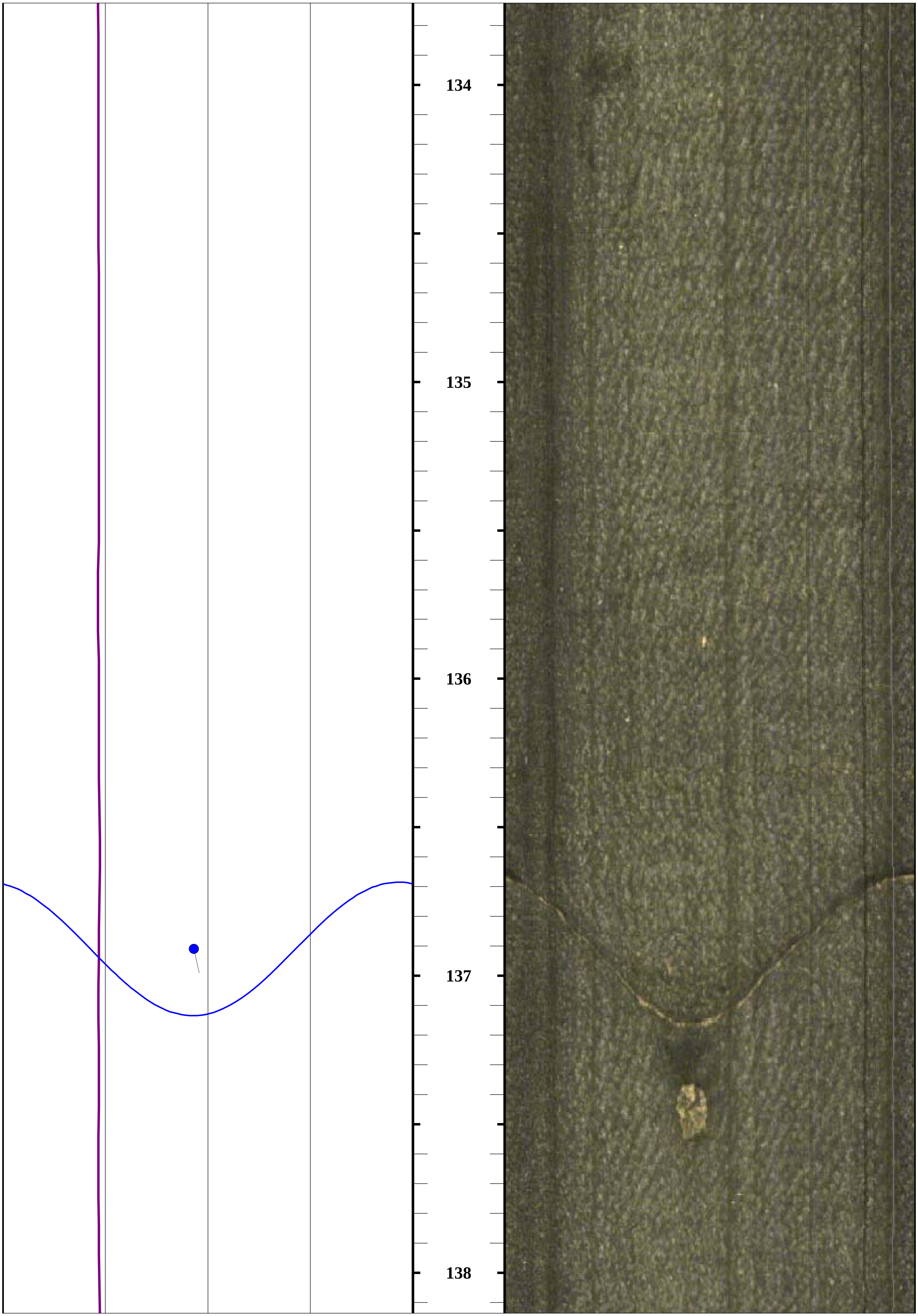
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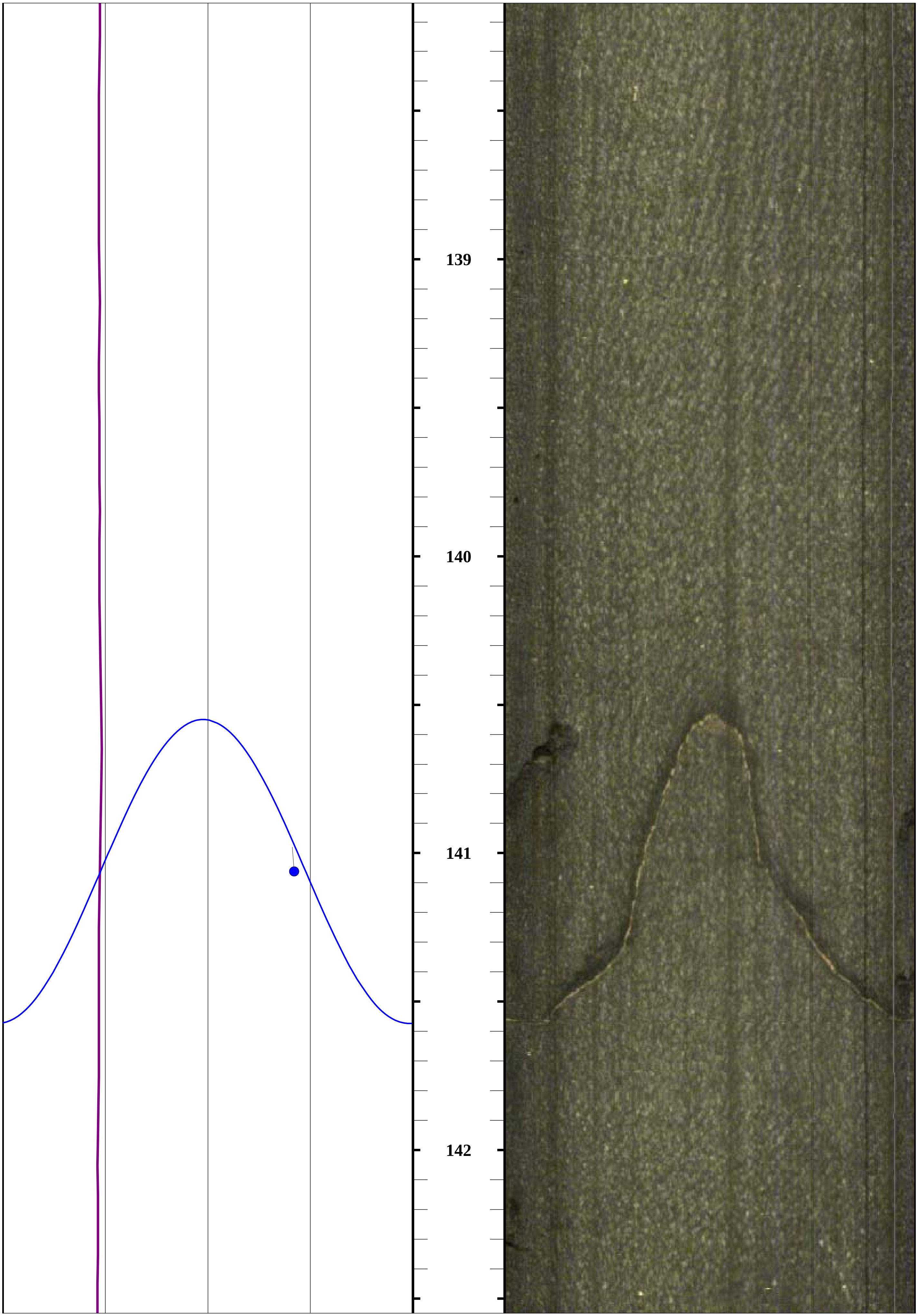

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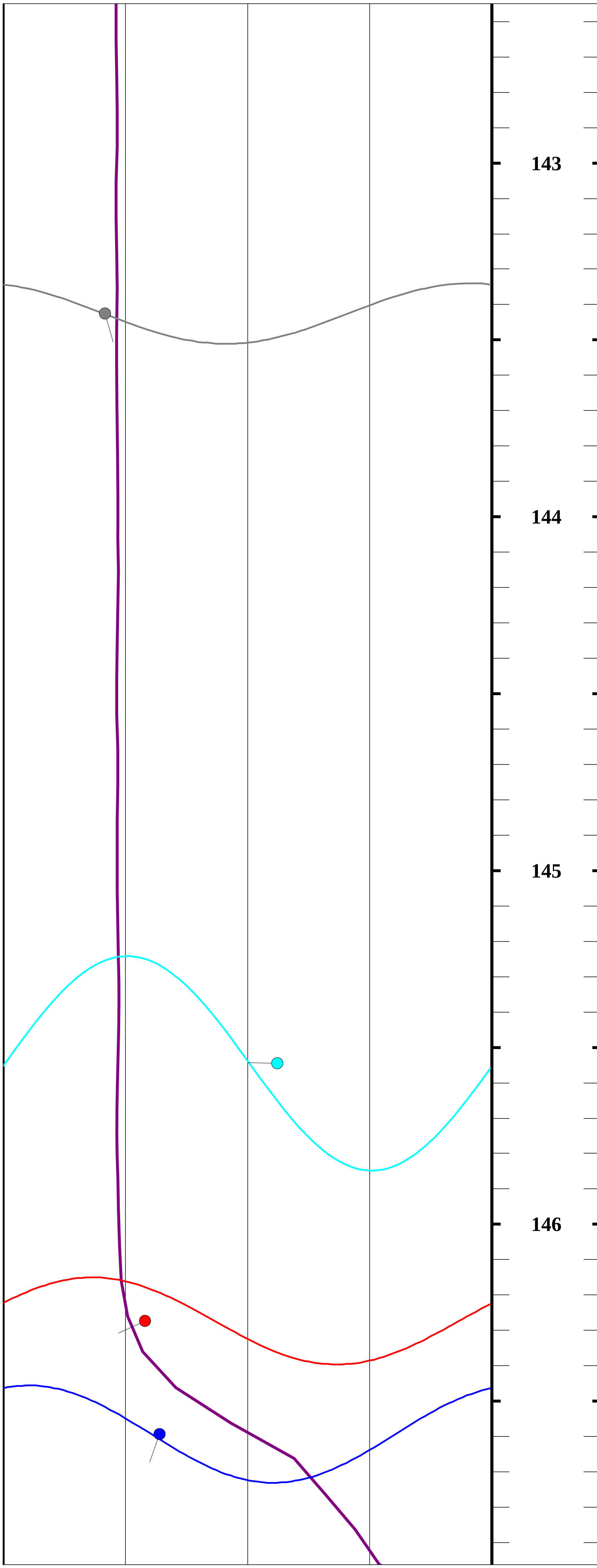
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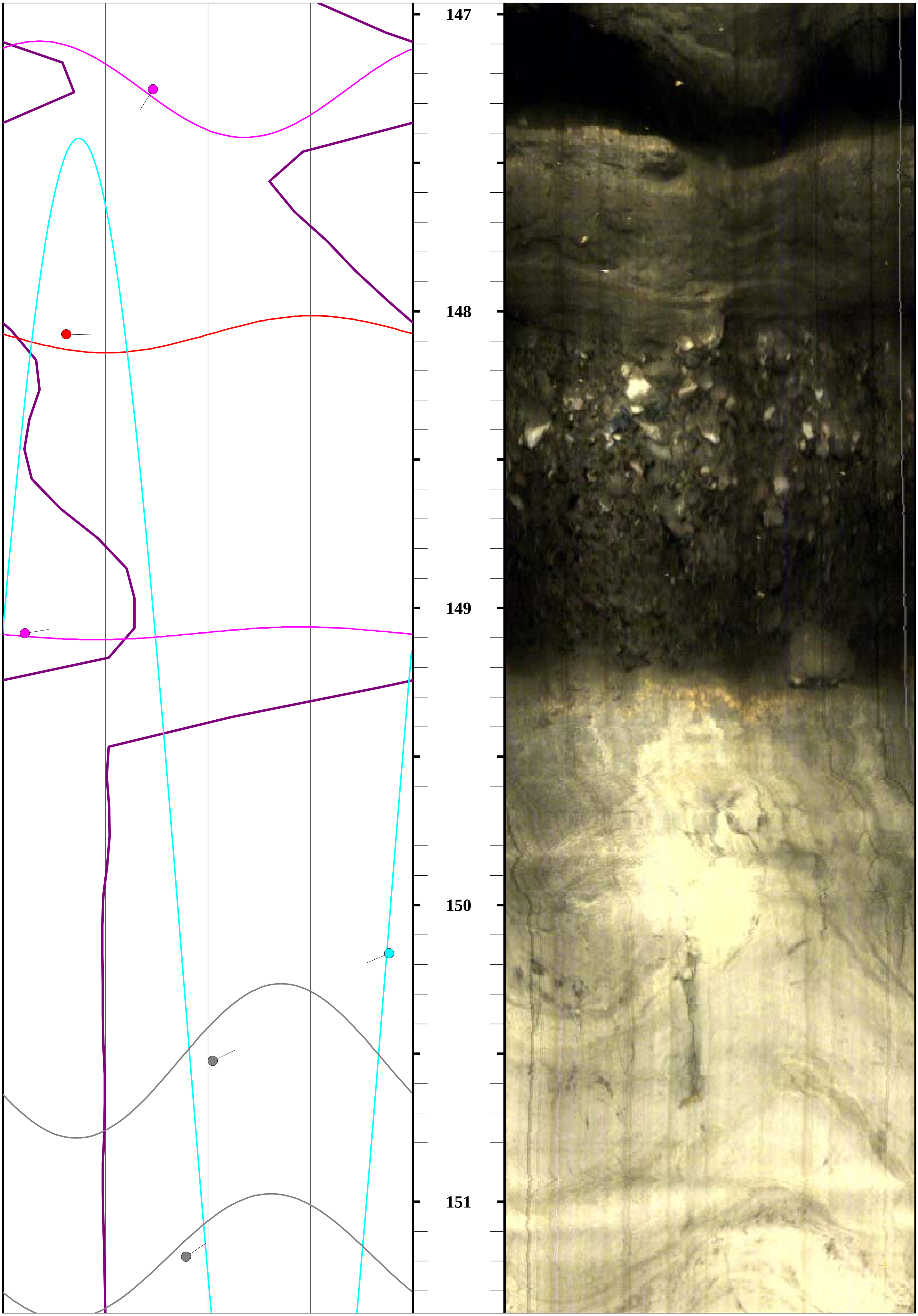
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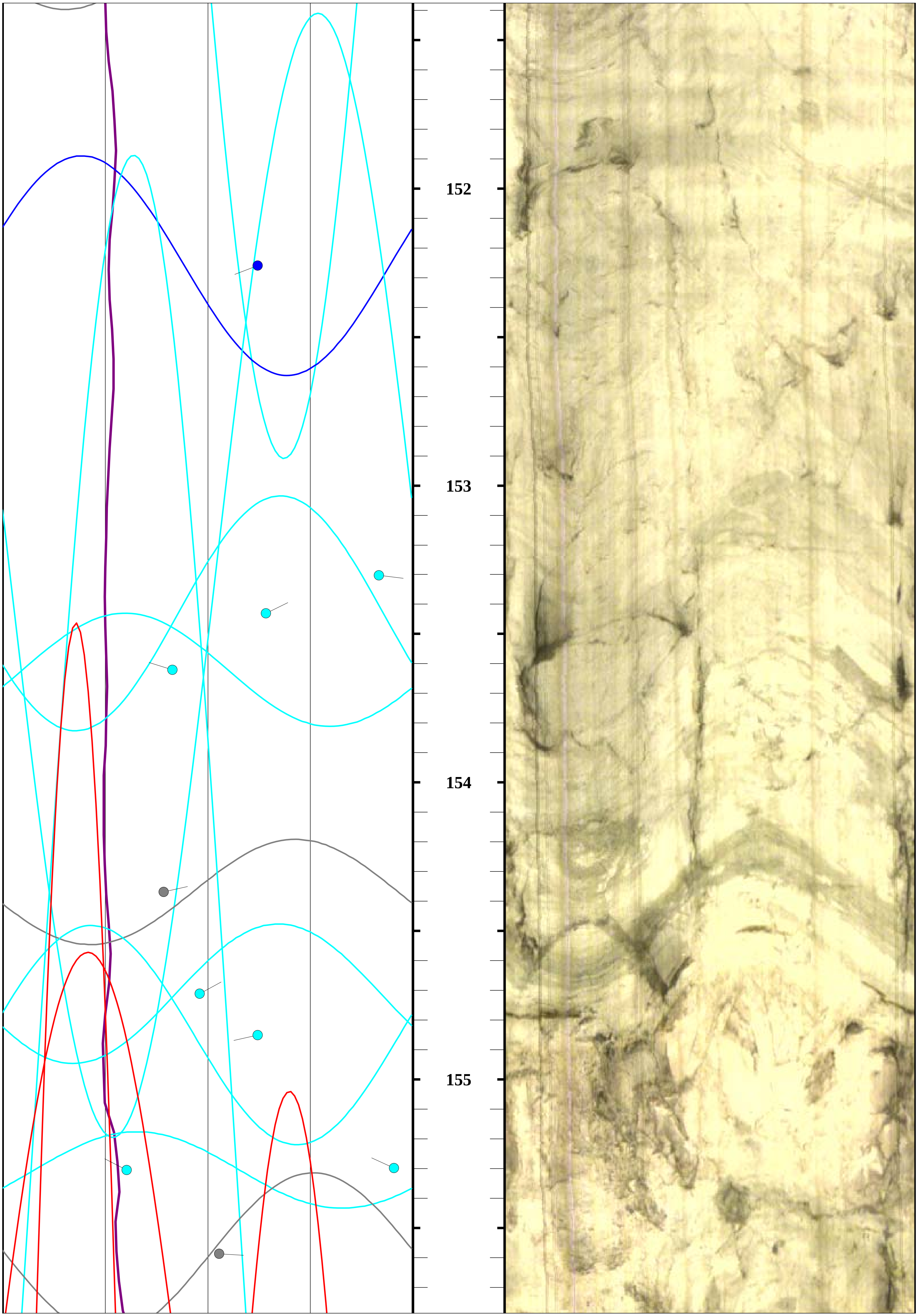
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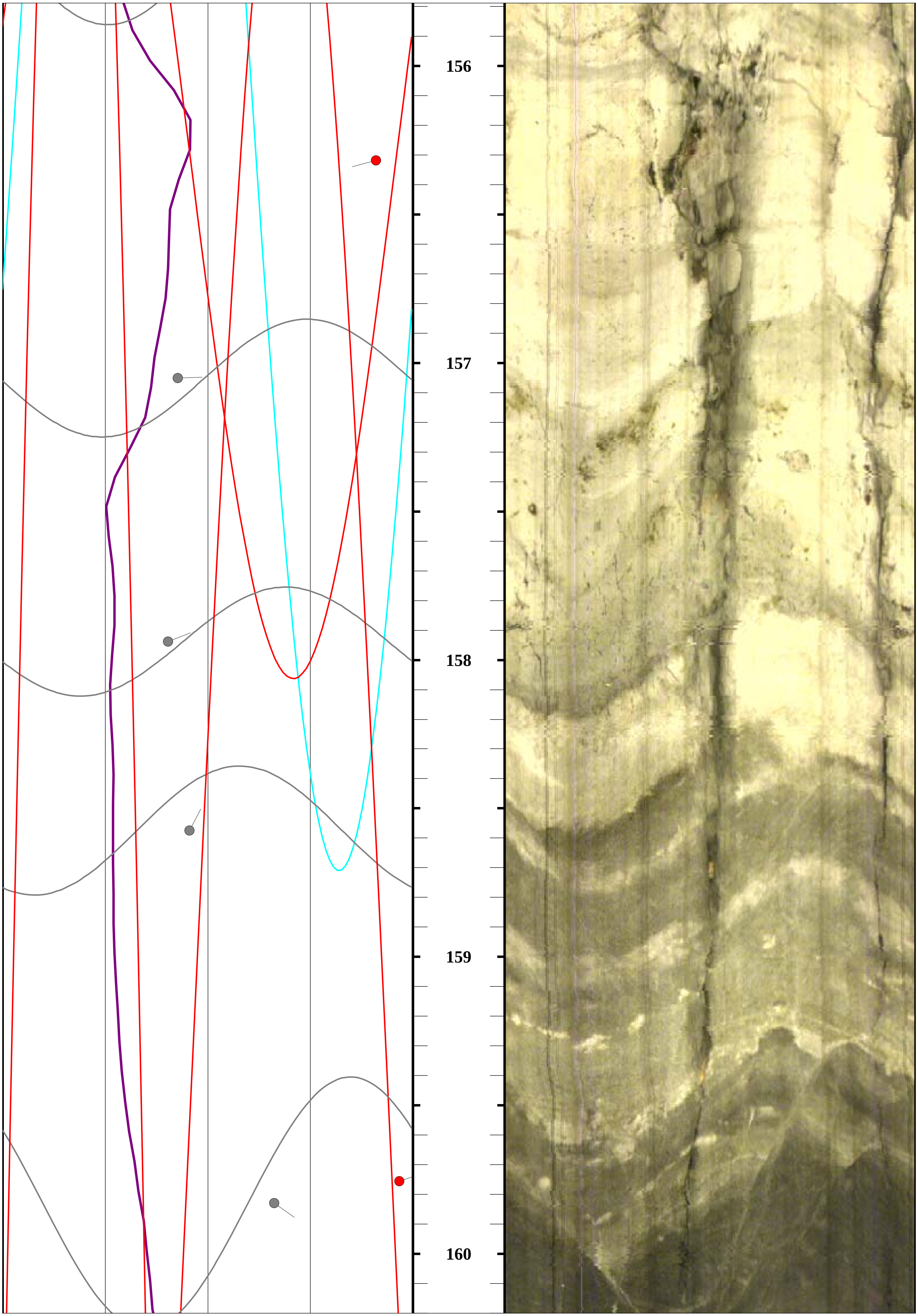
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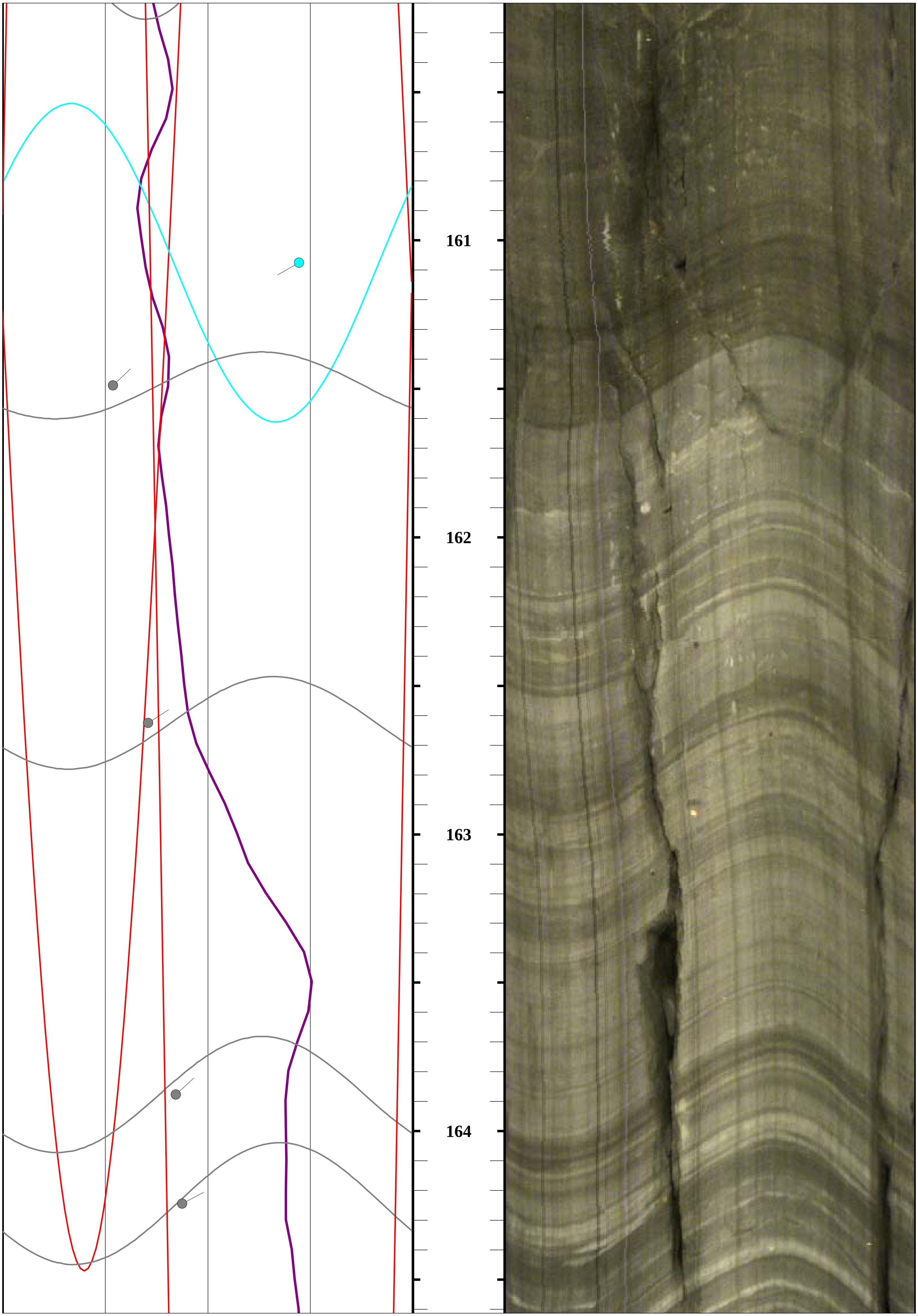
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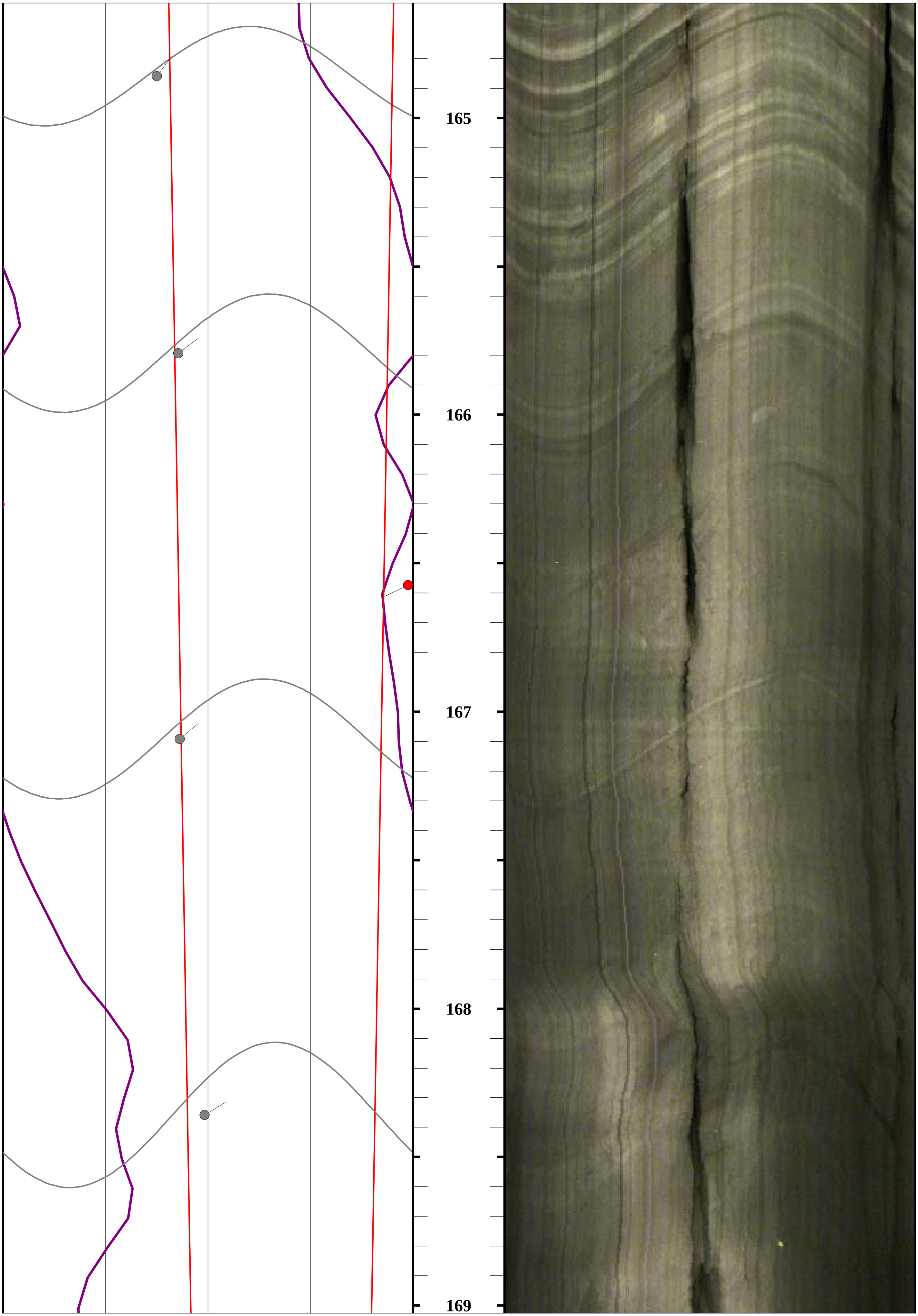
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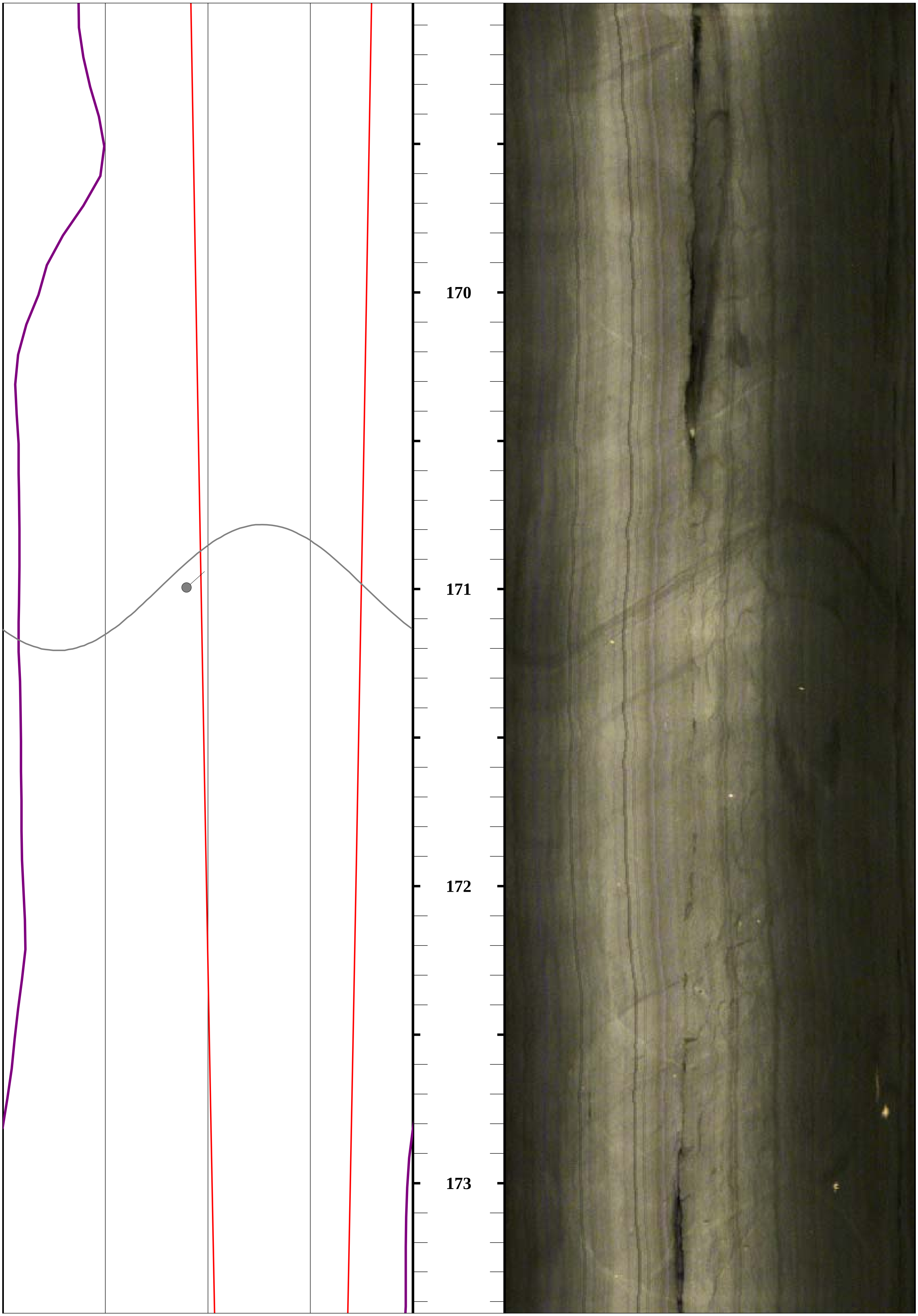
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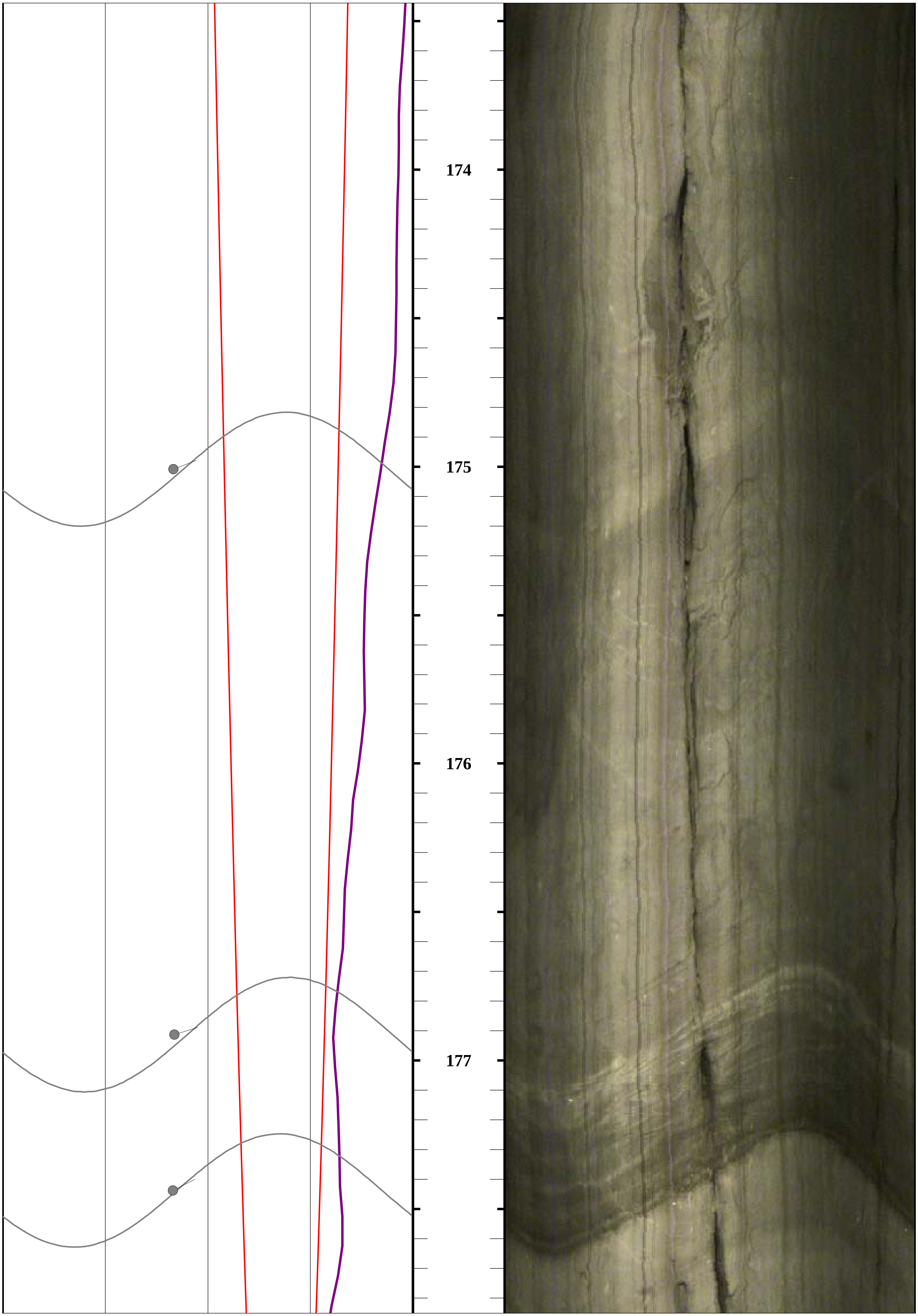
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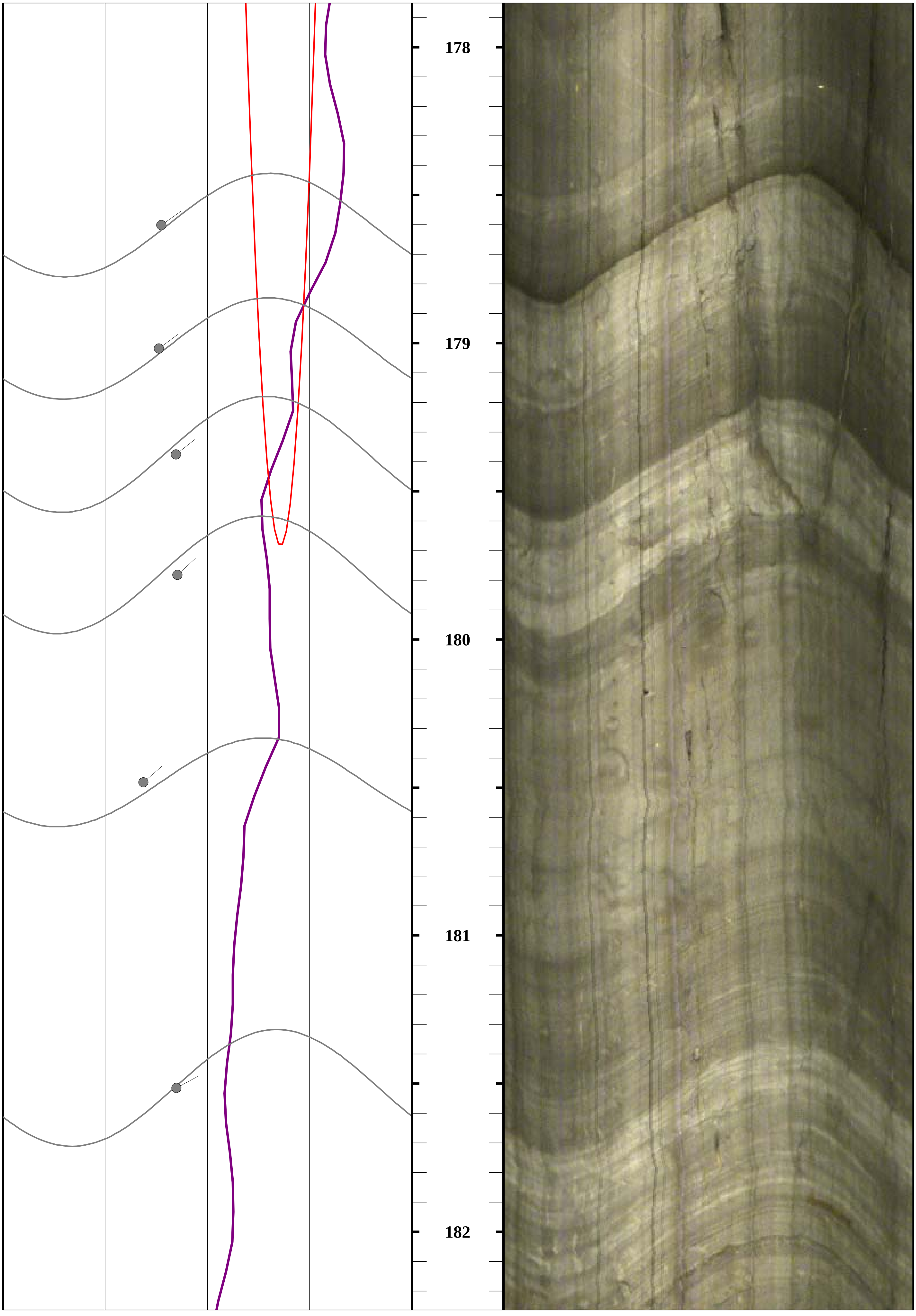
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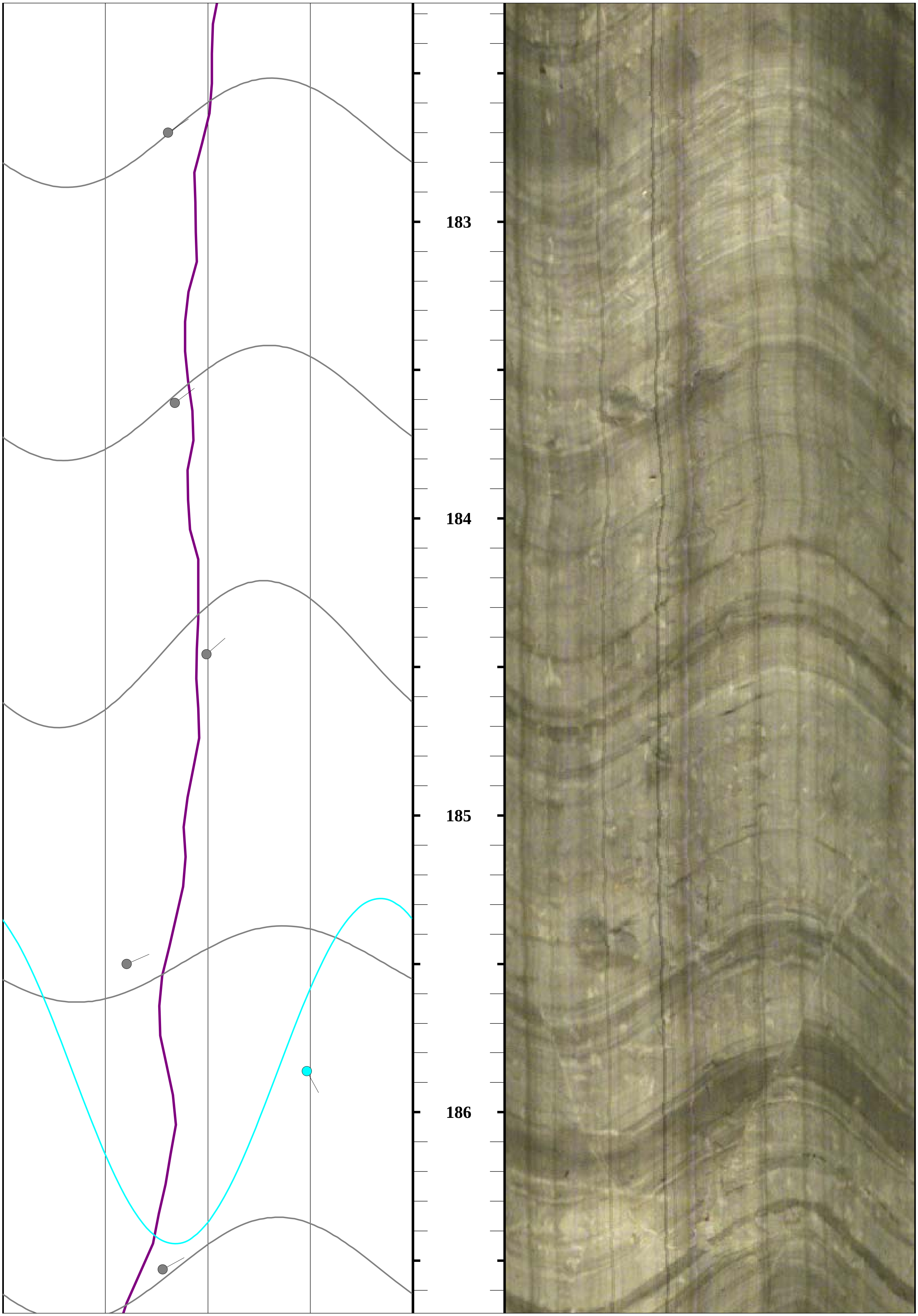
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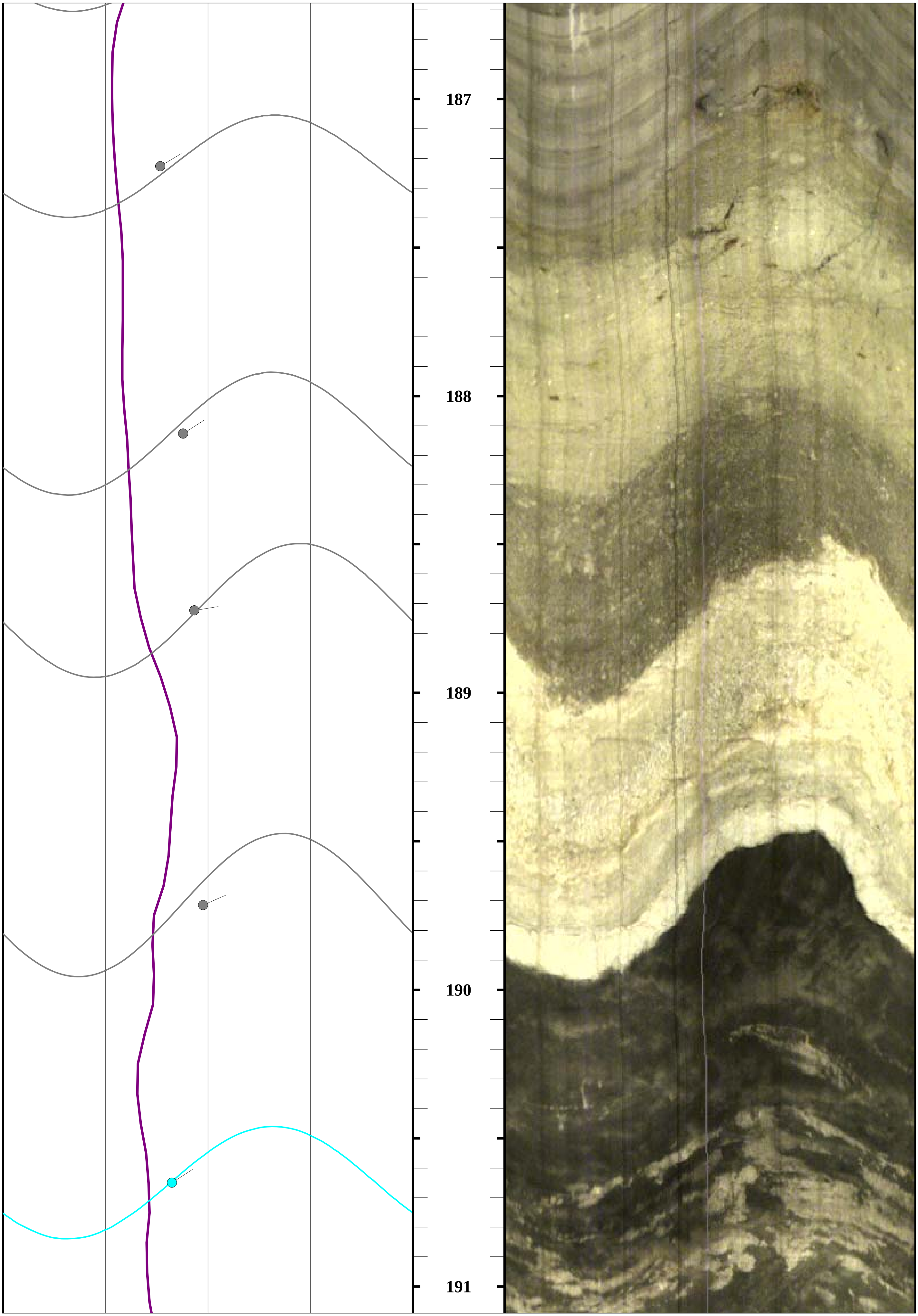
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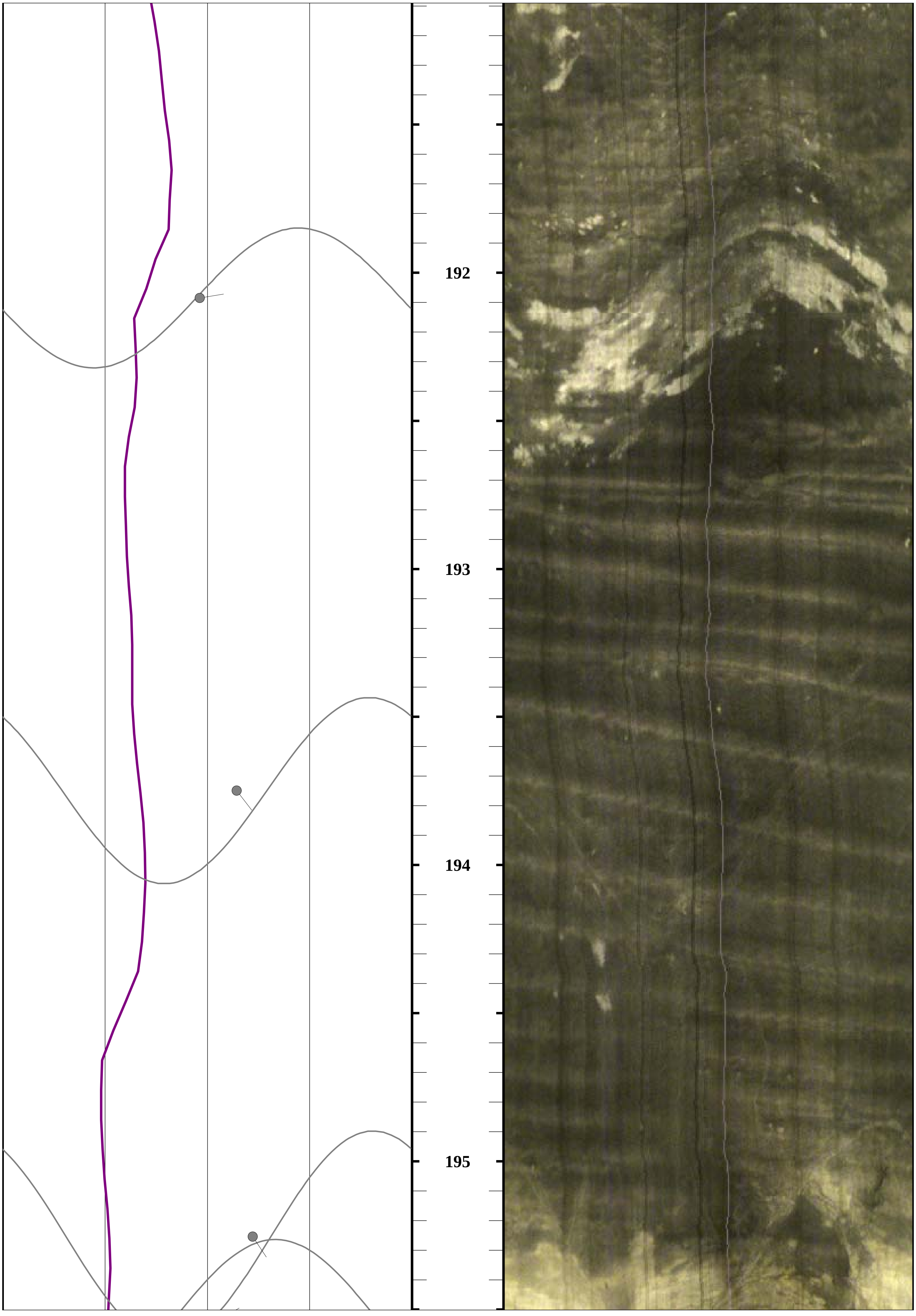
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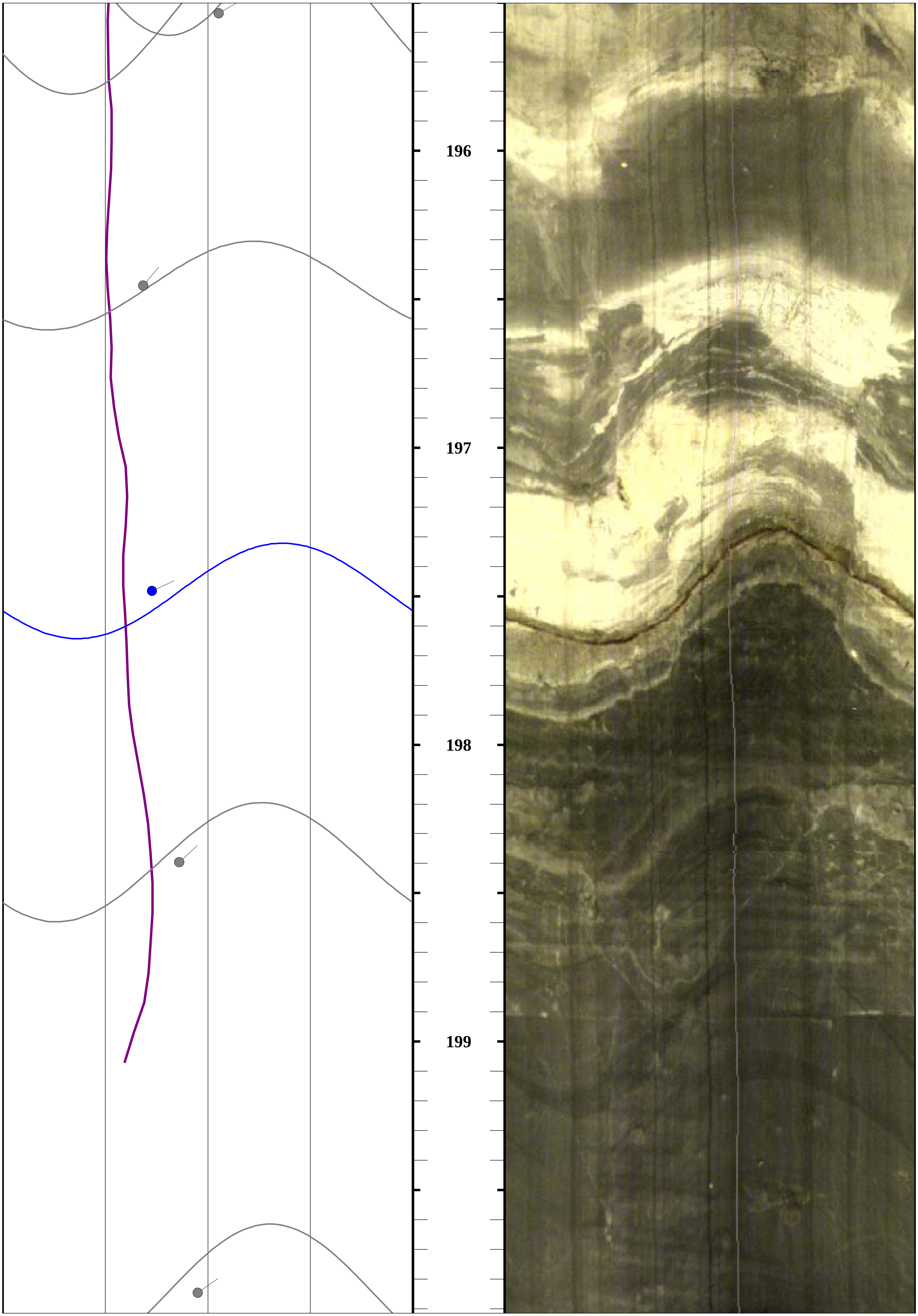
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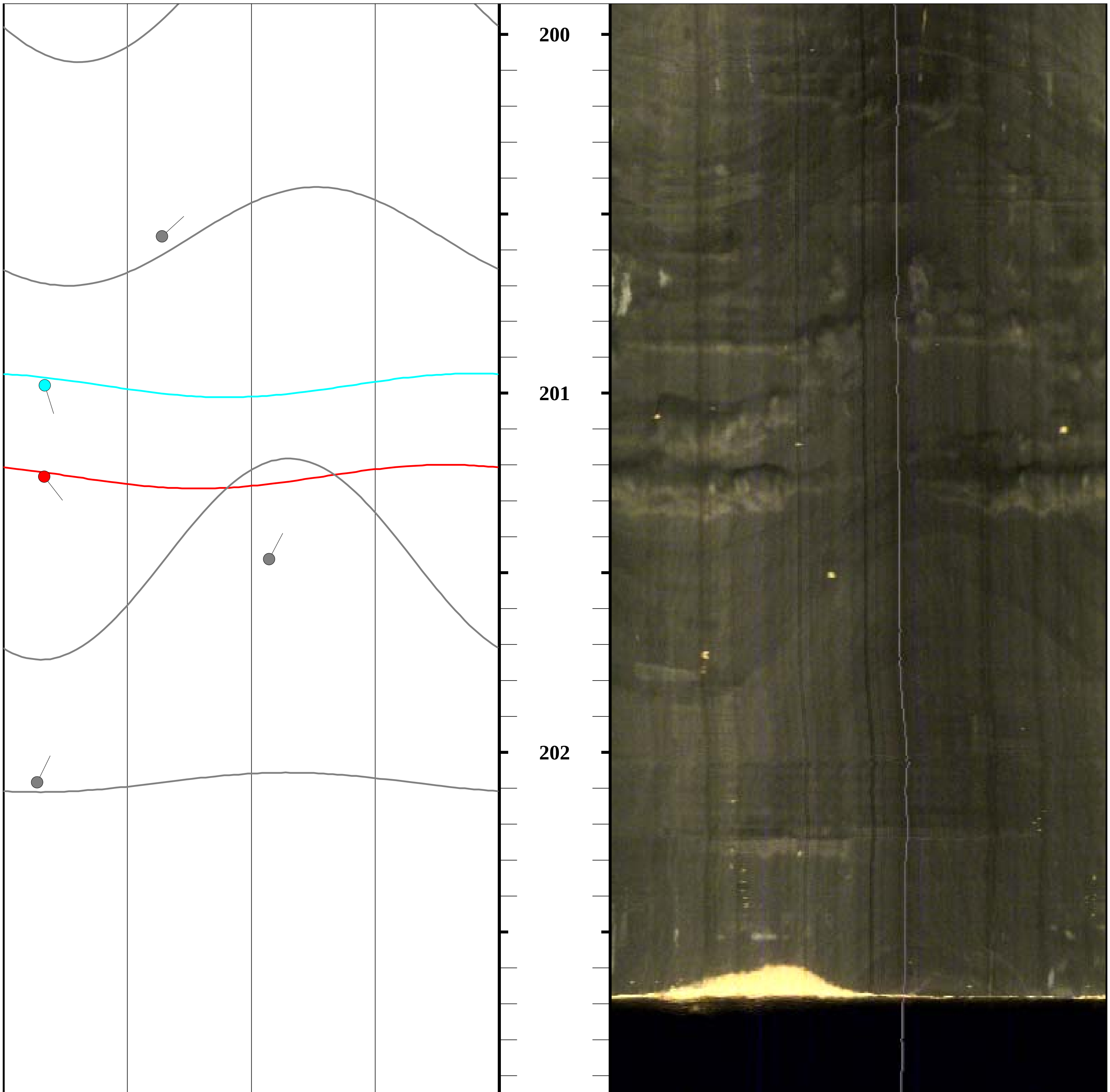


Tadpoles - MN		Depth	Optical Image - MN
0	90		
Projections - MN			
0° 90° 180° 270° 0°			
3-Arm Caliper		1ft:5ft	0° 90° 180° 270° 0°
5 in 9			

Orientation Summary Table
Image Features
WSP
Project: Nu-West CPO
Well: A-14
8 September 2011

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	18.80	61.7	168	44	3
2	18.85	61.8	115	28	3
3	19.32	63.4	307	42	1
4	19.43	63.8	16	43	1
5	19.43	63.8	180	76	3
6	19.62	64.4	105	33	1
7	19.66	64.5	30	76	3
8	20.42	67.0	242	60	3
9	20.88	68.5	158	57	1
10	21.21	69.6	166	9	1
11	21.43	70.3	306	17	2
12	21.87	71.8	170	8	1
13	22.02	72.3	149	51	4
14	22.16	72.7	338	30	4
15	22.72	74.5	67	33	1
16	23.47	77.0	110	21	1
17	23.81	78.1	278	34	2
18	24.28	79.7	31	24	3
19	24.67	81.0	316	14	1
20	24.83	81.5	280	22	2
21	25.16	82.5	131	68	2
22	25.90	85.0	268	12	2
23	26.08	85.6	13	84	2
24	26.94	88.4	219	47	3
25	27.02	88.7	211	25	3
26	27.14	89.1	25	61	2
27	27.63	90.6	56	40	2
28	27.72	91.0	236	76	1
29	27.80	91.2	81	49	1
30	27.99	91.8	250	43	2
31	28.04	92.0	74	19	3
32	28.46	93.4	203	71	3
33	28.48	93.4	276	35	3
34	28.65	94.0	53	19	3
35	28.73	94.3	296	82	1
36	28.75	94.3	270	56	3
37	29.86	98.0	160	72	2
38	30.18	99.0	187	45	2
39	30.57	100.3	343	47	4
40	30.95	101.5	88	57	2
41	30.99	101.7	293	54	1
42	31.02	101.8	112	19	2
43	31.48	103.3	71	6	2
44	31.56	103.6	188	44	2
45	31.81	104.4	352	20	1

All directions are with respect to Magnetic North.

Orientation Summary Table
Image Features
WSP
Project: Nu-West CPO
Well: A-14
8 September 2011

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	32.05	105.2	84	71	4
47	32.25	105.8	103	57	2
48	32.48	106.6	279	28	1
49	33.20	108.9	344	39	1
50	33.45	109.8	38	11	1
51	33.59	110.2	40	14	1
52	34.04	111.7	211	45	3
53	34.31	112.6	150	39	2
54	34.42	112.9	336	81	2
55	34.69	113.8	2	42	1
56	34.98	114.8	264	10	2
57	35.23	115.6	207	6	2
58	35.65	117.0	176	24	1
59	35.93	117.9	210	19	2
60	36.13	118.6	210	13	2
61	36.91	121.1	125	50	2
62	37.22	122.1	292	80	2
63	37.28	122.3	357	25	2
64	37.73	123.8	211	23	1
65	38.06	124.9	38	5	0
66	38.49	126.3	75	13	1
67	38.55	126.5	64	20	0
68	38.59	126.6	193	73	1
69	38.63	126.7	311	21	2
70	38.78	127.2	140	13	2
71	38.83	127.4	185	15	2
72	38.90	127.6	152	1	1
73	39.00	127.9	2	15	0
74	39.21	128.6	7	79	1
75	41.73	136.9	167	42	2
76	43.00	141.1	356	64	2
77	43.71	143.4	164	19	0
78	44.36	145.6	271	50	1
79	44.58	146.3	246	26	3
80	44.68	146.6	199	29	2
81	44.88	147.3	212	33	4
82	45.13	148.1	91	14	3
83	45.44	149.1	81	5	4
84	45.77	150.2	247	85	1
85	45.88	150.5	64	46	0
86	46.08	151.2	55	40	0
87	46.41	152.3	250	56	2
88	46.73	153.3	97	82	1
89	46.77	153.4	64	58	1
90	46.82	153.6	288	37	1

All directions are with respect to Magnetic North.

Orientation Summary Table
Image Features
WSP
Project: Nu-West CPO
Well: A-14
8 September 2011

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
91	47.05	154.4	77	35	0
92	47.16	154.7	62	43	1
93	47.20	154.9	258	56	1
94	47.34	155.3	295	86	1
95	47.34	155.3	298	27	1
96	47.42	155.6	92	47	0
97	47.65	156.3	255	82	3
98	47.87	157.1	87	38	0
99	48.14	157.9	68	36	0
100	48.33	158.6	28	41	0
101	48.69	159.8	72	87	3
102	48.72	159.8	125	60	0
103	49.10	161.1	240	65	1
104	49.22	161.5	47	24	0
105	49.57	162.6	58	32	0
106	49.95	163.9	47	38	0
107	50.06	164.2	63	39	0
108	50.25	164.9	36	34	0
109	50.53	165.8	53	39	0
110	50.77	166.6	244	89	3
111	50.93	167.1	50	39	0
112	51.32	168.4	59	44	0
113	52.12	171.0	48	40	0
114	53.34	175.0	69	38	0
115	53.92	176.9	72	38	0
116	54.08	177.4	63	37	0
117	54.44	178.6	55	35	0
118	54.57	179.0	53	34	0
119	54.67	179.4	52	38	0
120	54.80	179.8	48	38	0
121	55.01	180.5	49	31	0
122	55.32	181.5	61	38	0
123	55.69	182.7	56	36	0
124	55.96	183.6	54	38	0
125	56.22	184.5	49	45	0
126	56.54	185.5	66	27	0
127	56.65	185.9	151	67	1
128	56.85	186.5	62	35	0
129	57.07	187.2	58	35	0
130	57.34	188.1	57	40	0
131	57.52	188.7	81	42	0
132	57.83	189.7	67	44	0
133	58.11	190.7	57	37	1
134	58.55	192.1	80	43	0
135	59.06	193.8	142	51	0

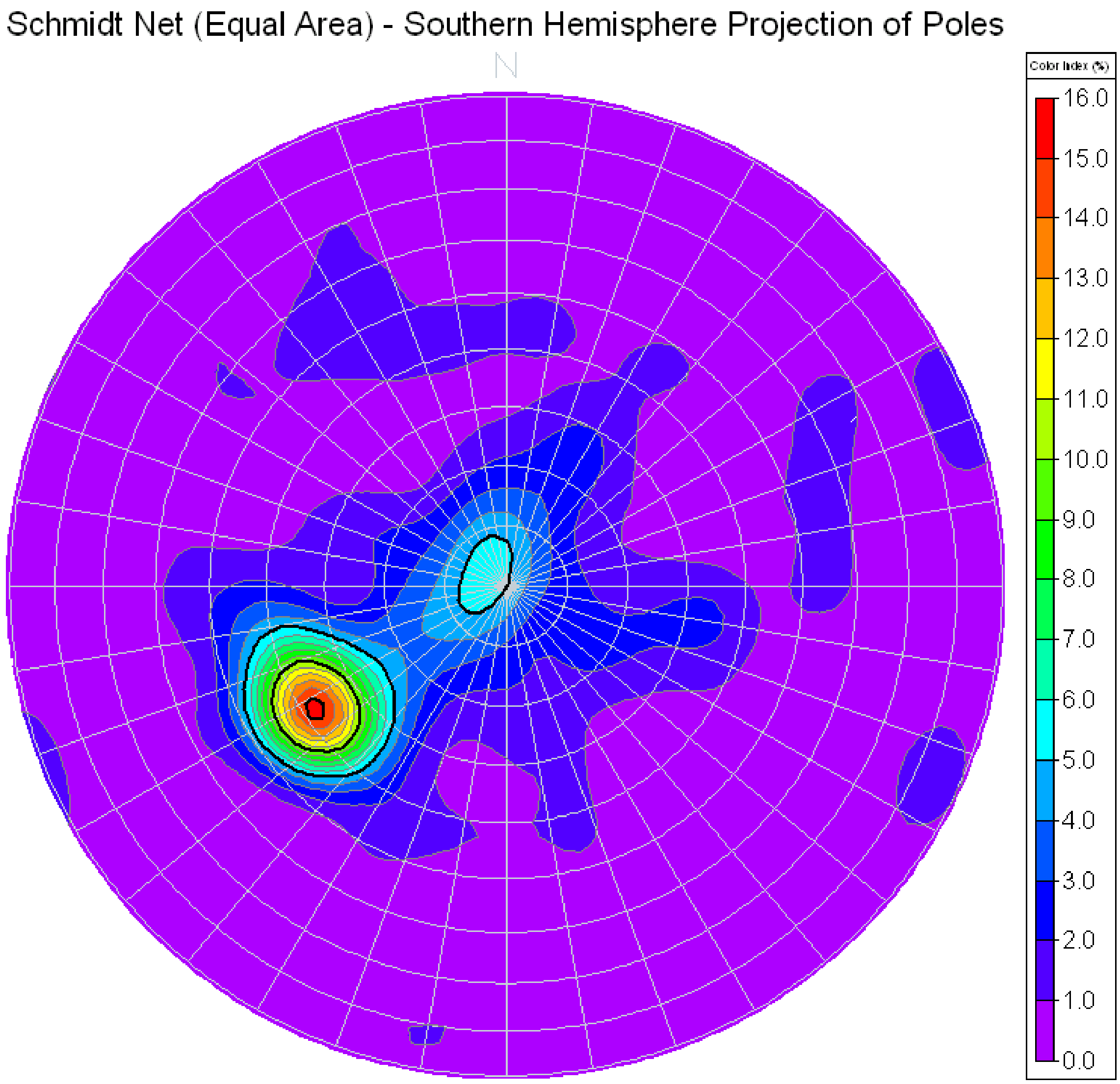
All directions are with respect to Magnetic North.

Orientation Summary Table
Image Features
WSP
Project: Nu-West CPO
Well: A-14
8 September 2011

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
136	59.51	195.3	146	55	0
137	59.60	195.5	60	47	0
138	59.88	196.5	40	31	0
139	60.19	197.5	66	33	2
140	60.47	198.4	47	39	0
141	60.91	199.9	55	43	0
142	61.13	200.6	47	29	0
143	61.26	201.0	162	8	1
144	61.33	201.2	141	8	3
145	61.41	201.5	27	48	0
146	61.59	202.1	26	6	0

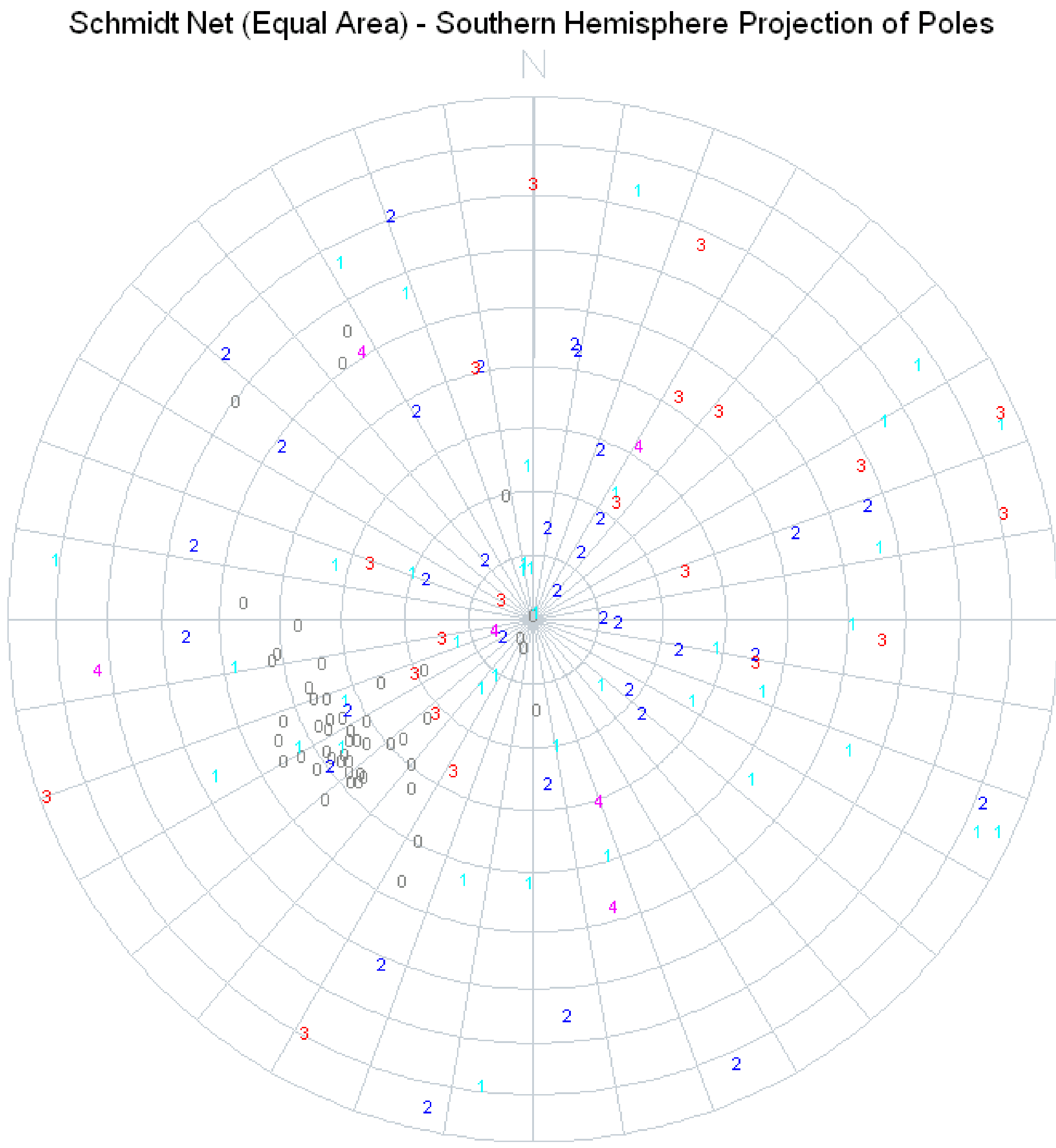
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Image Features
WSP
Project: Nu-West CPO
Well: A-14
8 September 2011



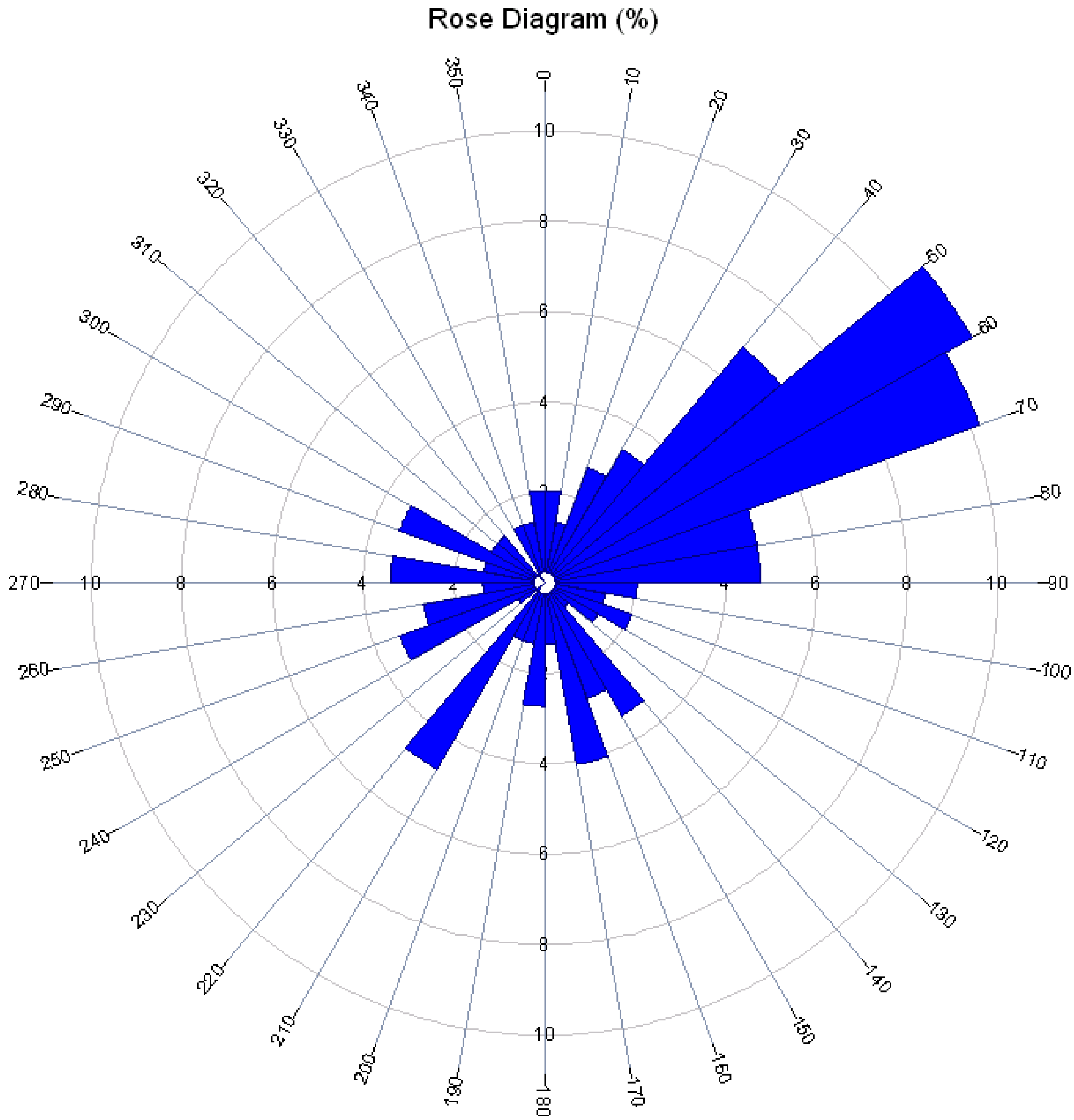
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Image Features
WSP
Project: Nu-West CPO
Well: A-14
8 September 2011



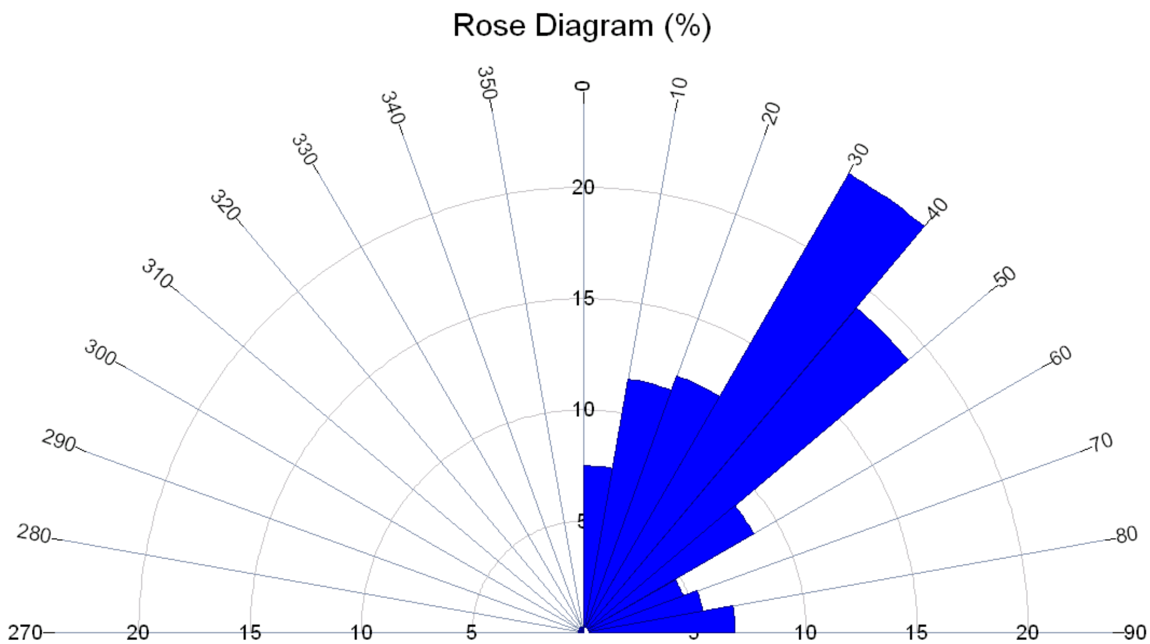
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Image Features
WSP
Project: Nu-West CPO
Well: A-14
8 September 2011



All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Image Features
WSP
Project: Nu-West CPO
Well: A-14
8 September 2011



All directions are with respect to Magnetic North.

Appendix B
A-15 Geophysical Data

Geophysical/Hydrophysical Summary Plot

BOREHOLE GEOPHYSICS & HYDROPHYSICS
COLOG
A DIVISION OF LAYNE CHRISTENSEN COMPANY

COMPANY: WSP	PROJECT: Nu-West
DATE LOGGED: 9-10 Sept 2011	WELL: A-15

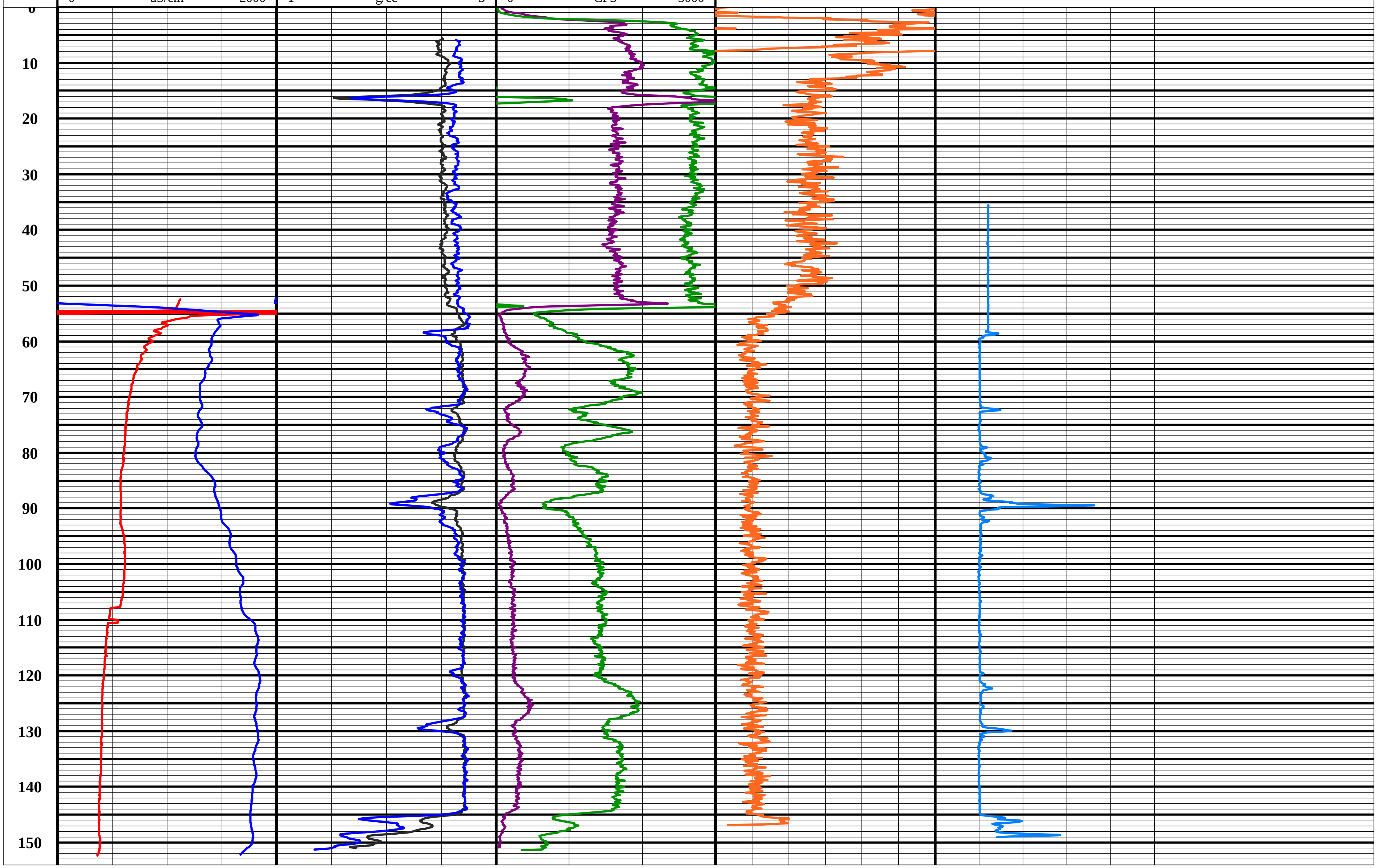
COLOG Main Office

810 Quail Street, Suite E, Lakewood, CO 80215

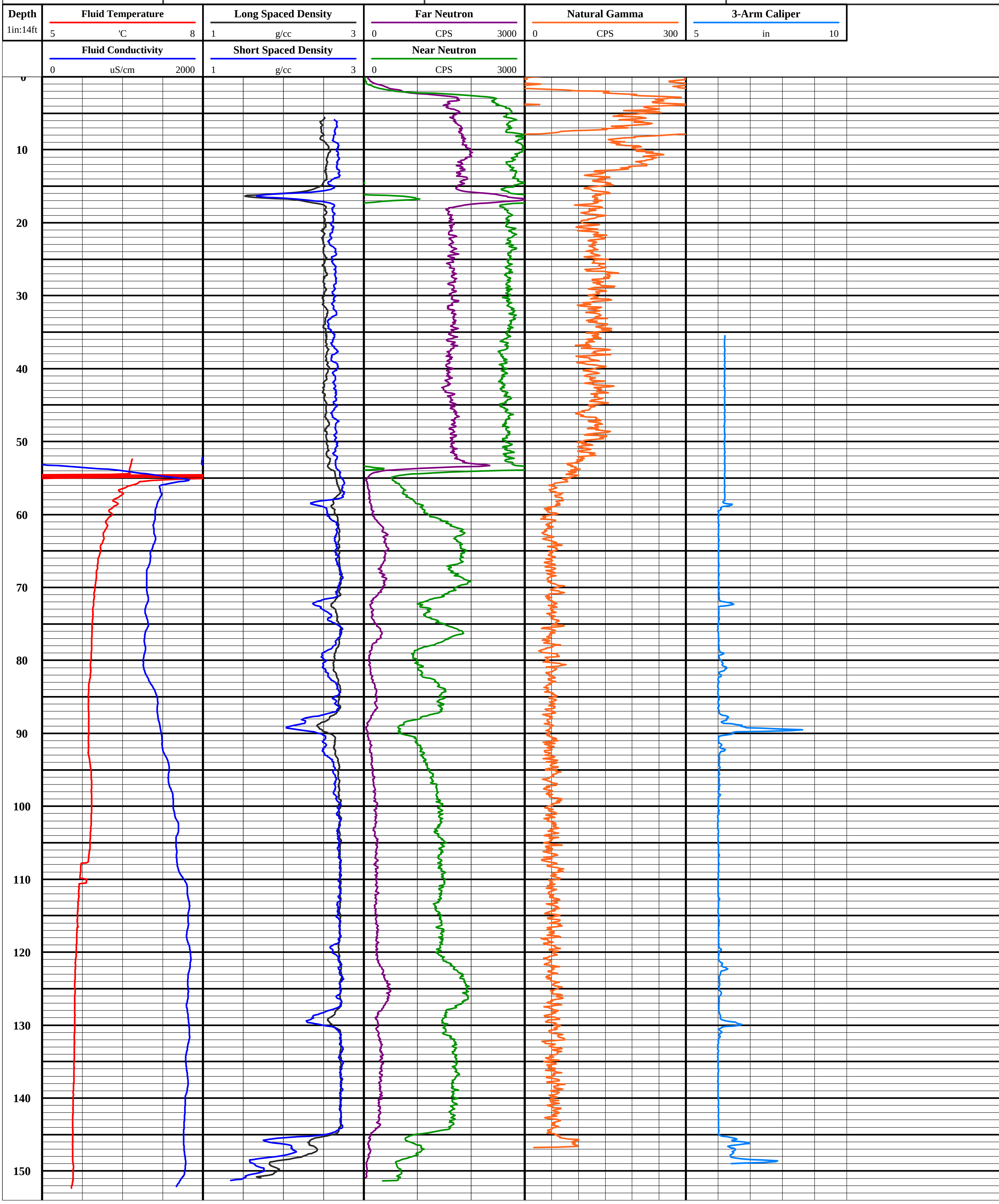
Phone: (303) 279-0171, Fax: (303) 278-0135

www.colog.com

Depth 1in:25ft	Fluid Temperature 5 'C 8	Long Spaced Density 1 g/cc 3	Far Neutron 0 CPS 3000	Natural Gamma 0 CPS 300	3-Arm Caliper 5 in 10
	Fluid Conductivity 0 uS/cm 2000	Short Spaced Density 1 g/cc 3	Near Neutron 0 CPS 3000		



	Geophysical/Hydrophysical Summary Plot		COLOG Main Office
COLOG	COMPANY: **WSP**	PROJECT: **Nu-West**	810 Quail Street, Suite E, Lakewood, CO 80215
	DATE LOGGED: **9-10 Sept 2011**	WELL: **A-15**	Phone: (303) 279-0171, Fax: (303) 278-0135 www.colog.com



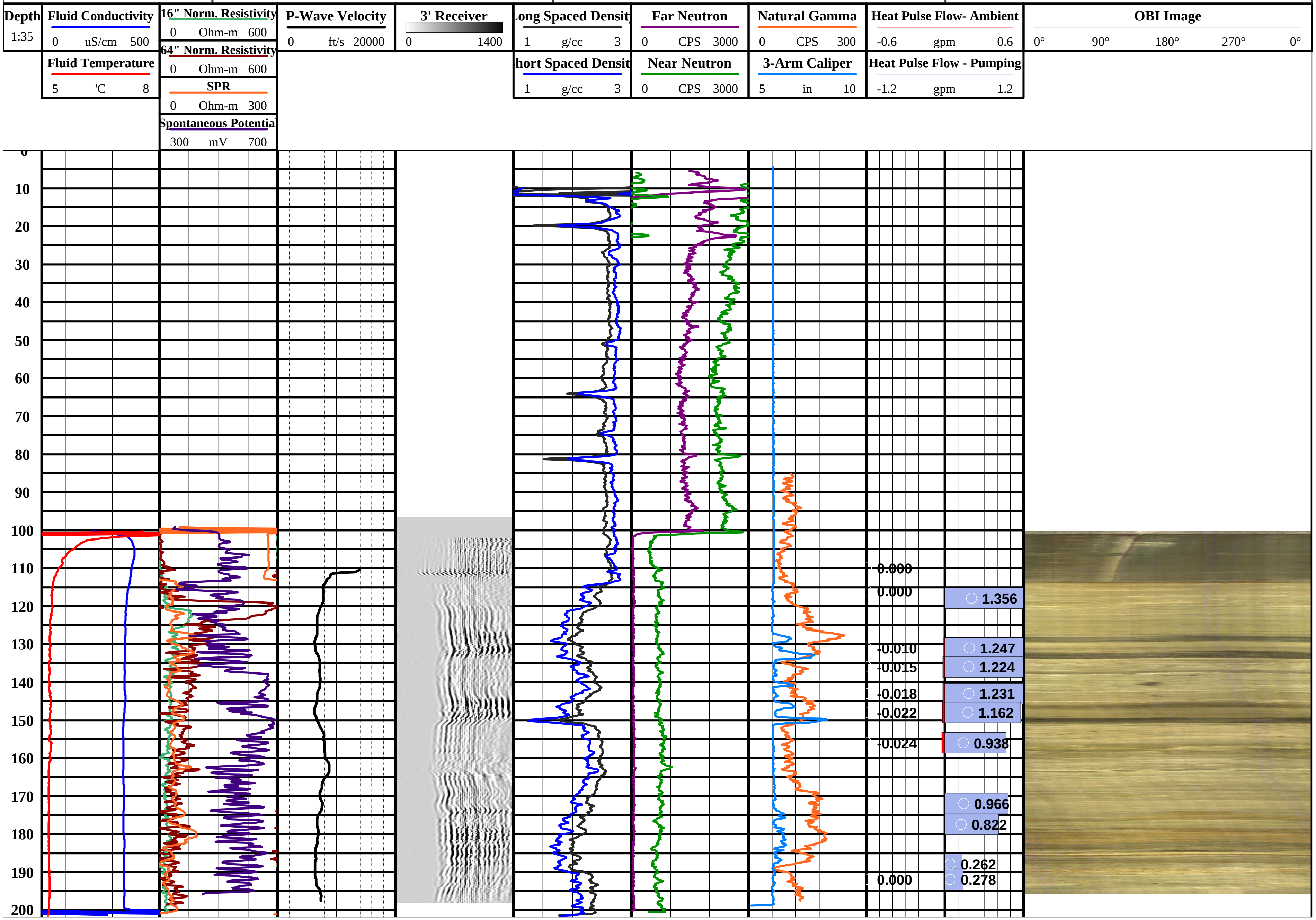
Appendix C
A-16 Geophysical Data

Geophysical/Hydrophysical Summary Plot

BOREHOLE GEOPHYSICS & HYDROPHYSICS
COLOG
A DIVISION OF LAYNE CHRISTENSEN COMPANY

COMPANY: WSP	PROJECT: Nu-West CPO
DATE LOGGED: 10 Sept. 2011	WELL: A-16

COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com



Geophysical/Hydrophysical Summary Plot

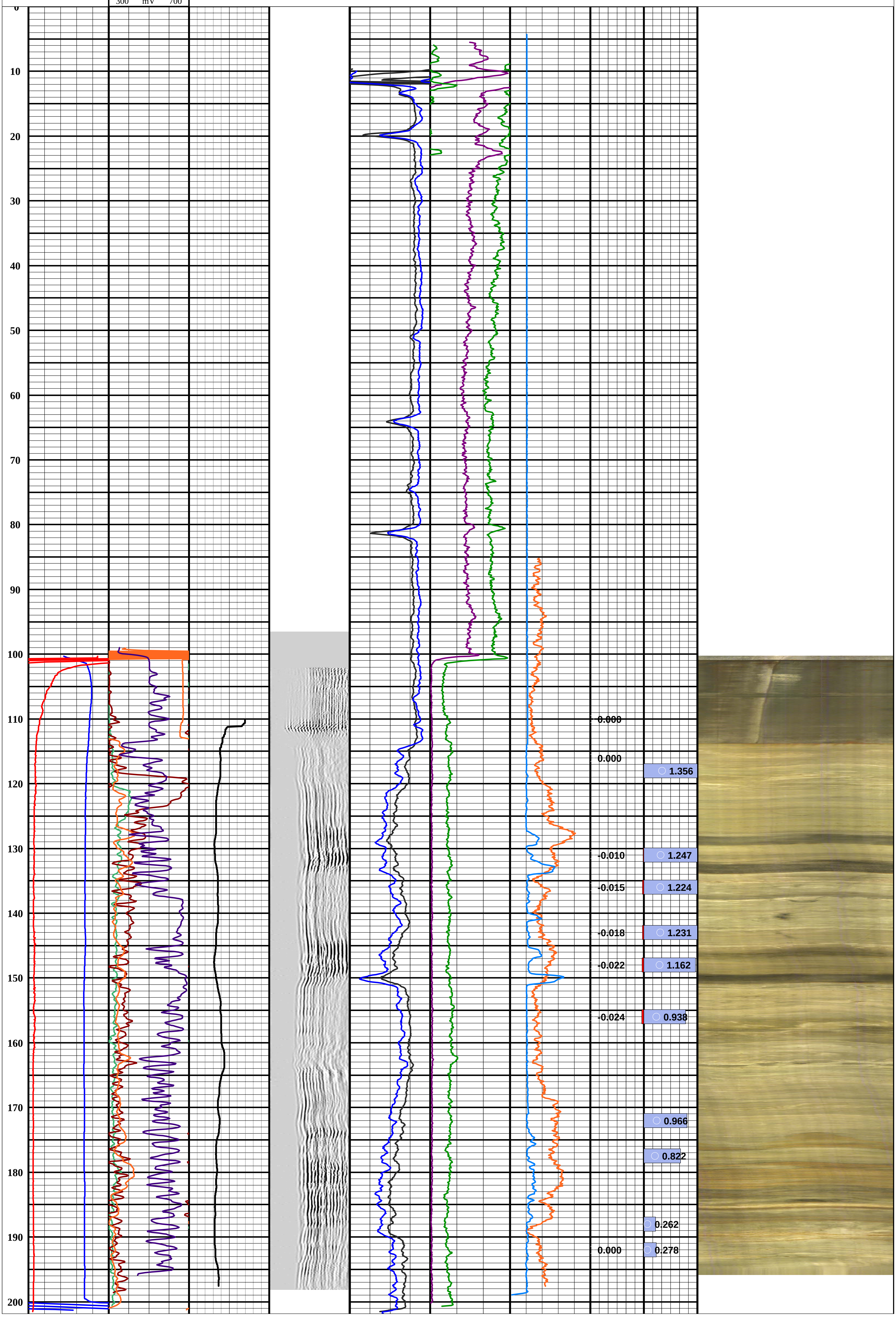
COLOG — Borehole Geophysics & Hydrophysics — A Division of Layne Christensen Company

COMPANY: WSP | PROJECT: Nu-West CPO

DATE LOGGED: 10 Sept. 2011 | WELL: A-16

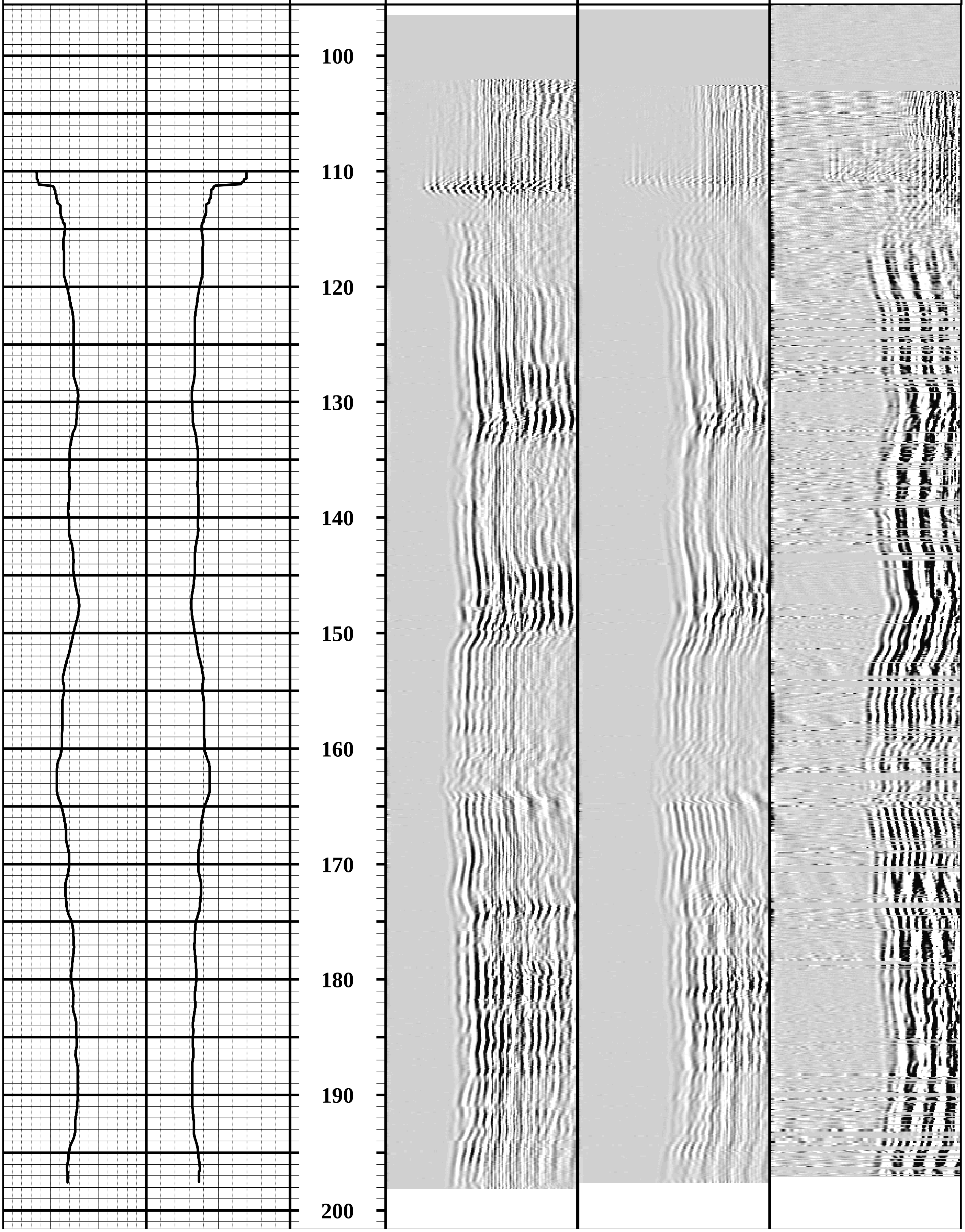
COLOG Main Office
810 Quail Street, Suite E, Lakewood, CO 80215
Phone: (303) 279-0171, Fax: (303) 278-0135
www.colog.com

Depth 1:14		
	Fluid Conductivity	0 uS/cm 500
	Fluid Temperature	5 'C 8
	16" Norm. Resistivity	0 Ohm-m 600
	64" Norm. Resistivity	0 Ohm-m 600
	SPR	0 Ohm-m 300
	Spontaneous Potential	300 mV 700
	P-Wave Velocity	0 ft/s 20000
	3' Receiver	0 1400
	Long Spaced Density	1 g/cc 3
	Short Spaced Density	1 g/cc 3
	Far Neutron	0 CPS 3000
	Near Neutron	0 CPS 3000
	Natural Gamma	0 CPS 300
	3-Arm Caliper	5 in 10
	Heat Pulse Flow- Ambient	-0.6 gpm 0.6
	Heat Pulse Flow - Pumping	-1.2 gpm 1.2
	OBI Image	0° 90° 180° 270° 0°



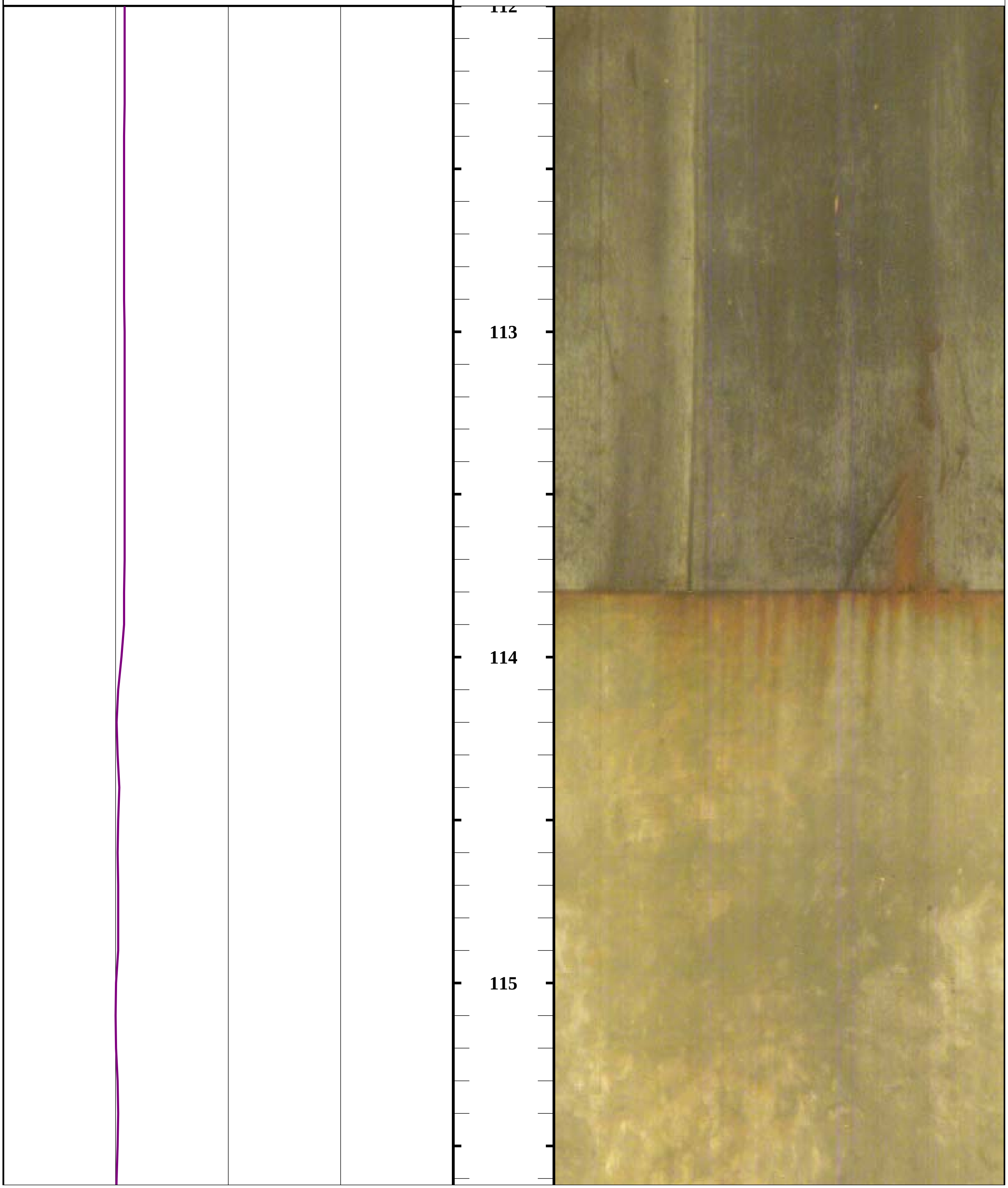
COLOG — Borehole Geophysics & Hydrophysics — A Division of Layne Christensen Company	**Full-Waveform Sonic**	**COLOG Main Office** 810 Quail Street, Suite E, Lakewood, CO 80215 Phone: (303) 279-0171, Fax: (303) 278-0135 www.colog.com
	COMPANY: WSP	PROJECT: Nu_West
	DATE LOGGED: 20 Sept. 2011	WELL: A-16

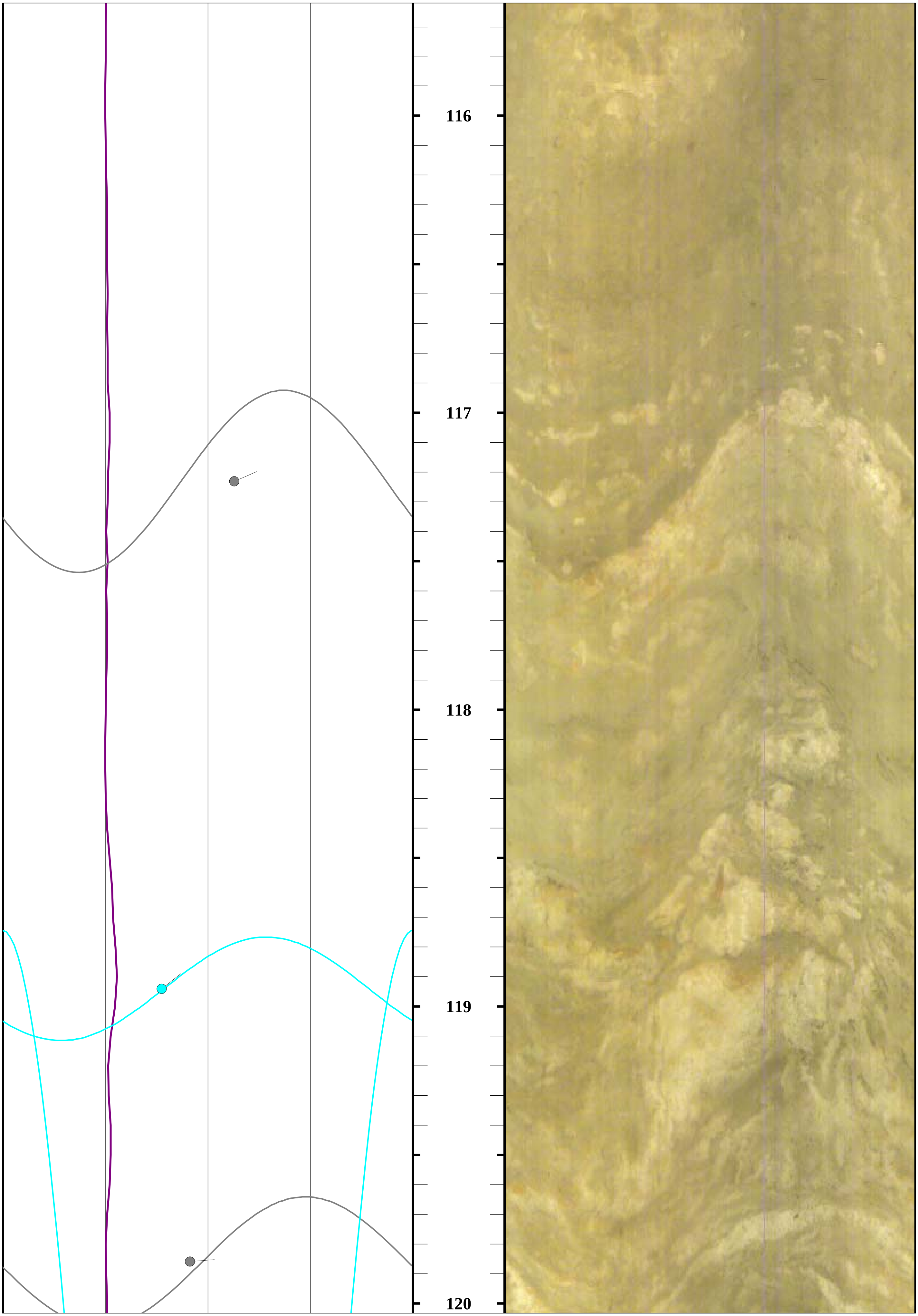
P-Wave Slowness	P-Wave Velocity	Depth	3' Receiver	4' Receiver	5' Receiver
0 us/ft 300	0 ft/s 20000	1ft:135ft	0 1400	0 1400	0 1400



COLOG	Optical Televiewer Image Plot		COLOG Main Office
	COMPANY: WSP	PROJECT: Nu-West CPO	810 Quail Street, Suite E, Lakewood, CO 80215
	DATE LOGGED: 9 Sept 2011	WELL: A-16	Phone: (303) 279-0171, Fax: (303) 278-0135
			www.colog.com

3-Arm Caliper	Depth	Optical Image - MN
5 in 9	1ft:5ft	0° 90° 180° 270° 0°
Projections - MN		
0° 90° 180° 270° 0°		
Tadpoles - MN		
0 90		

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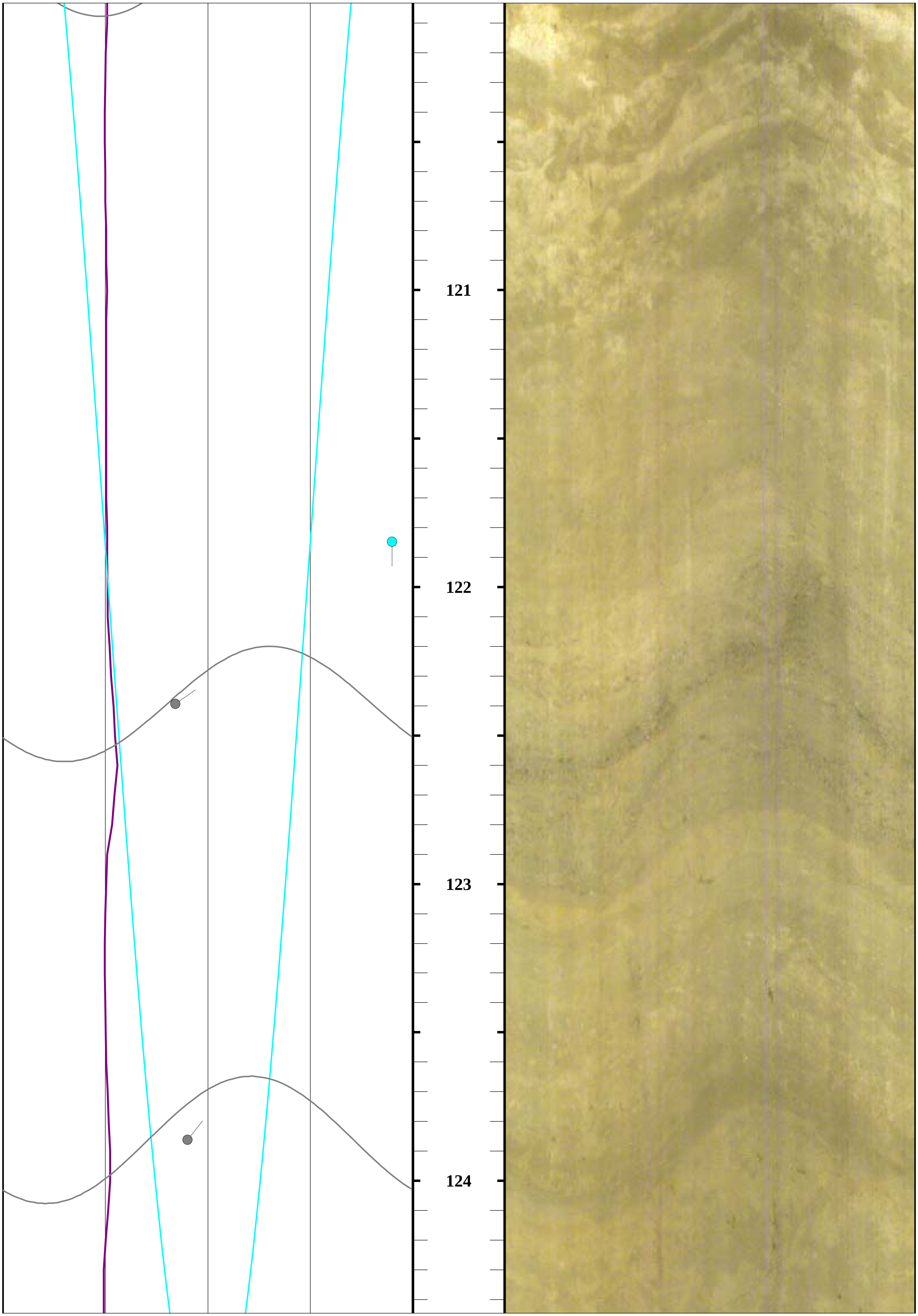
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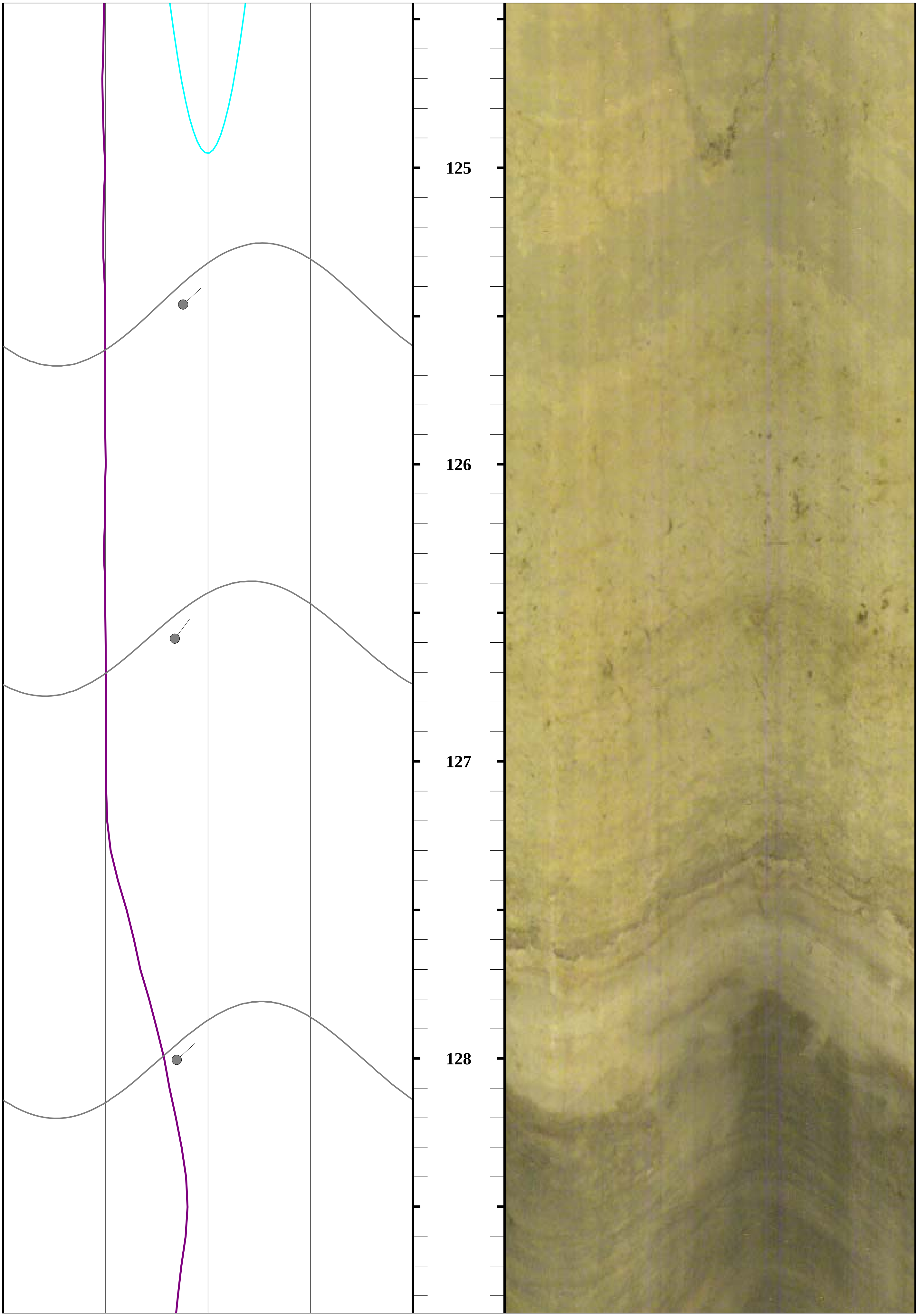
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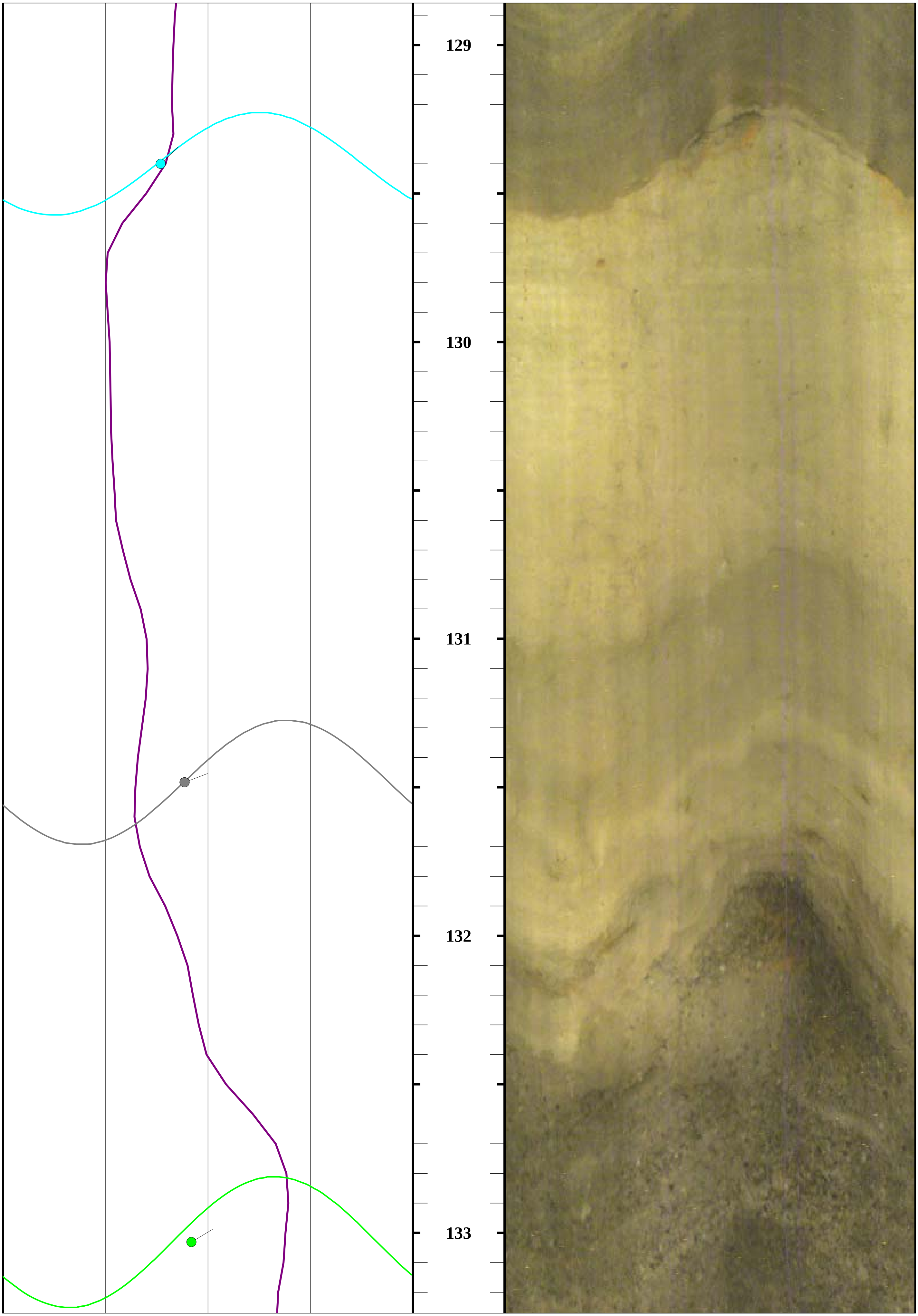
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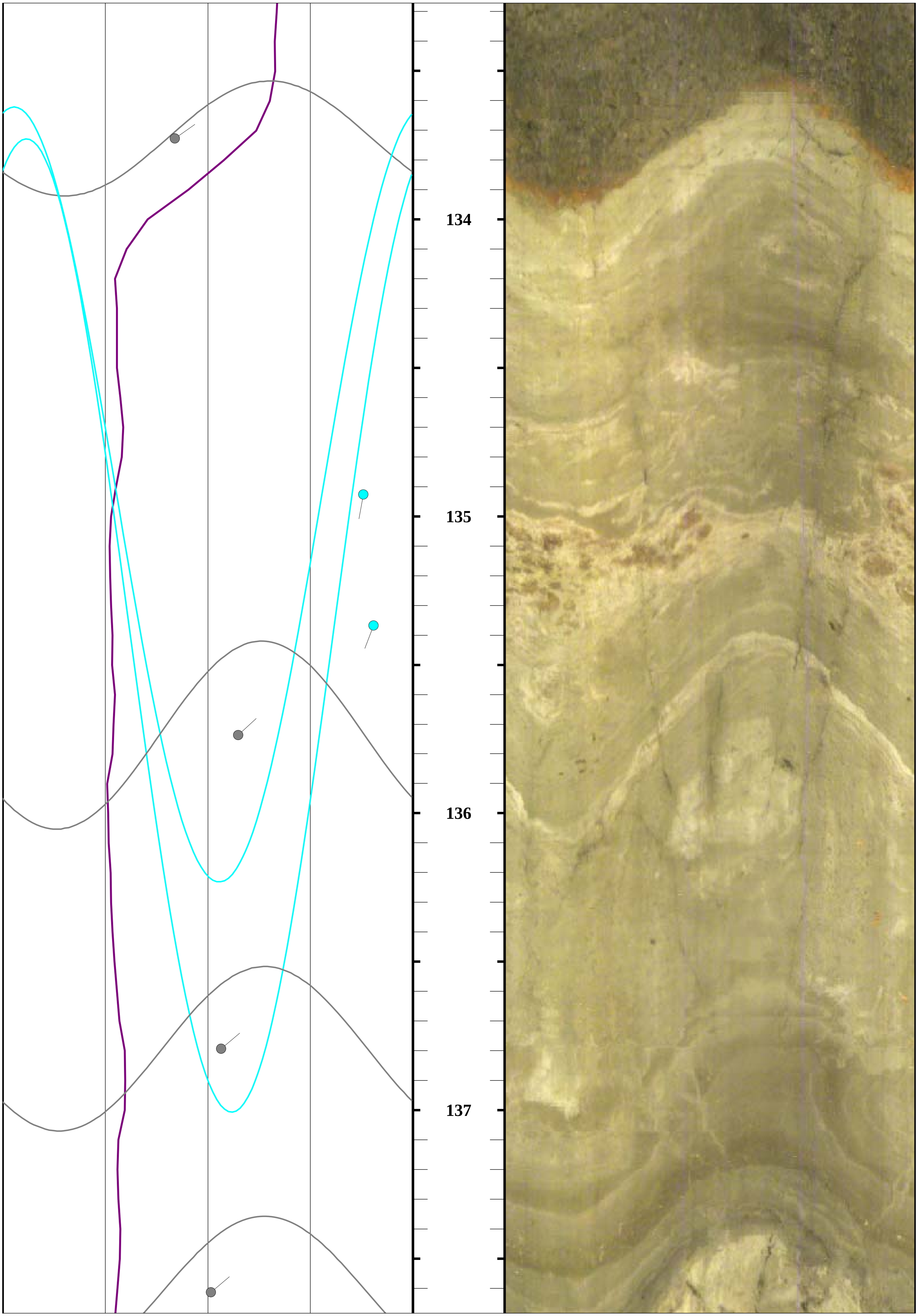
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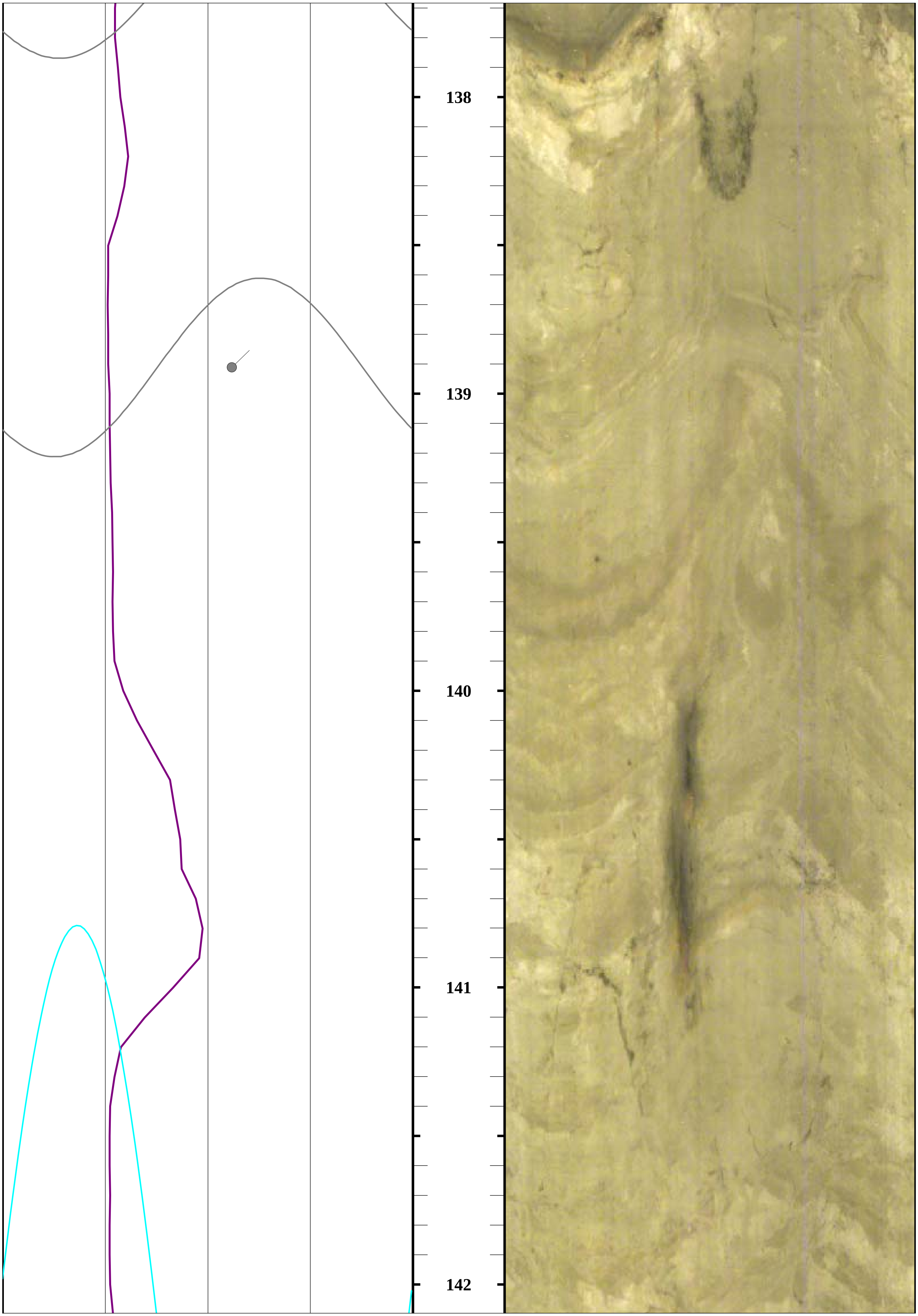
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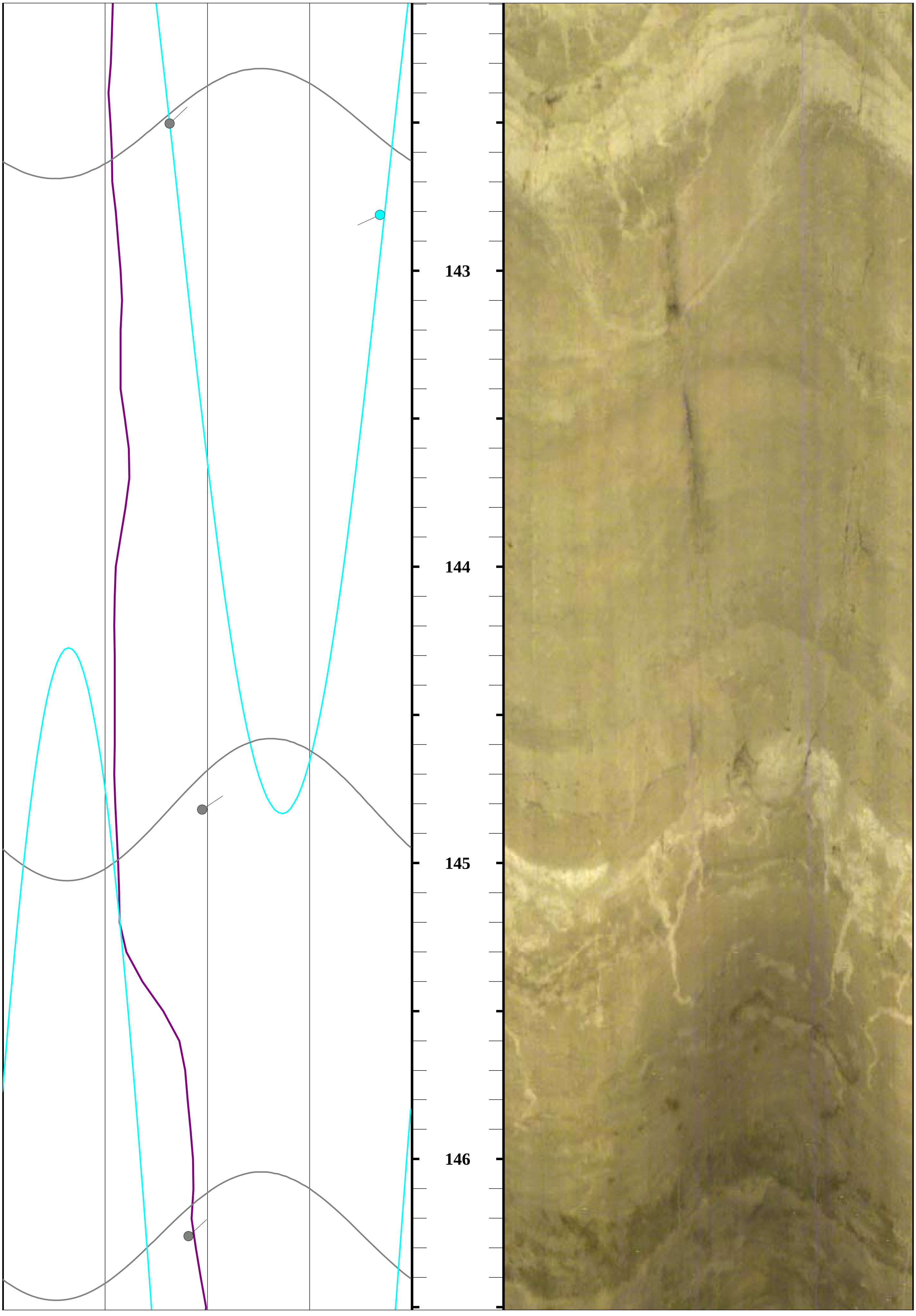

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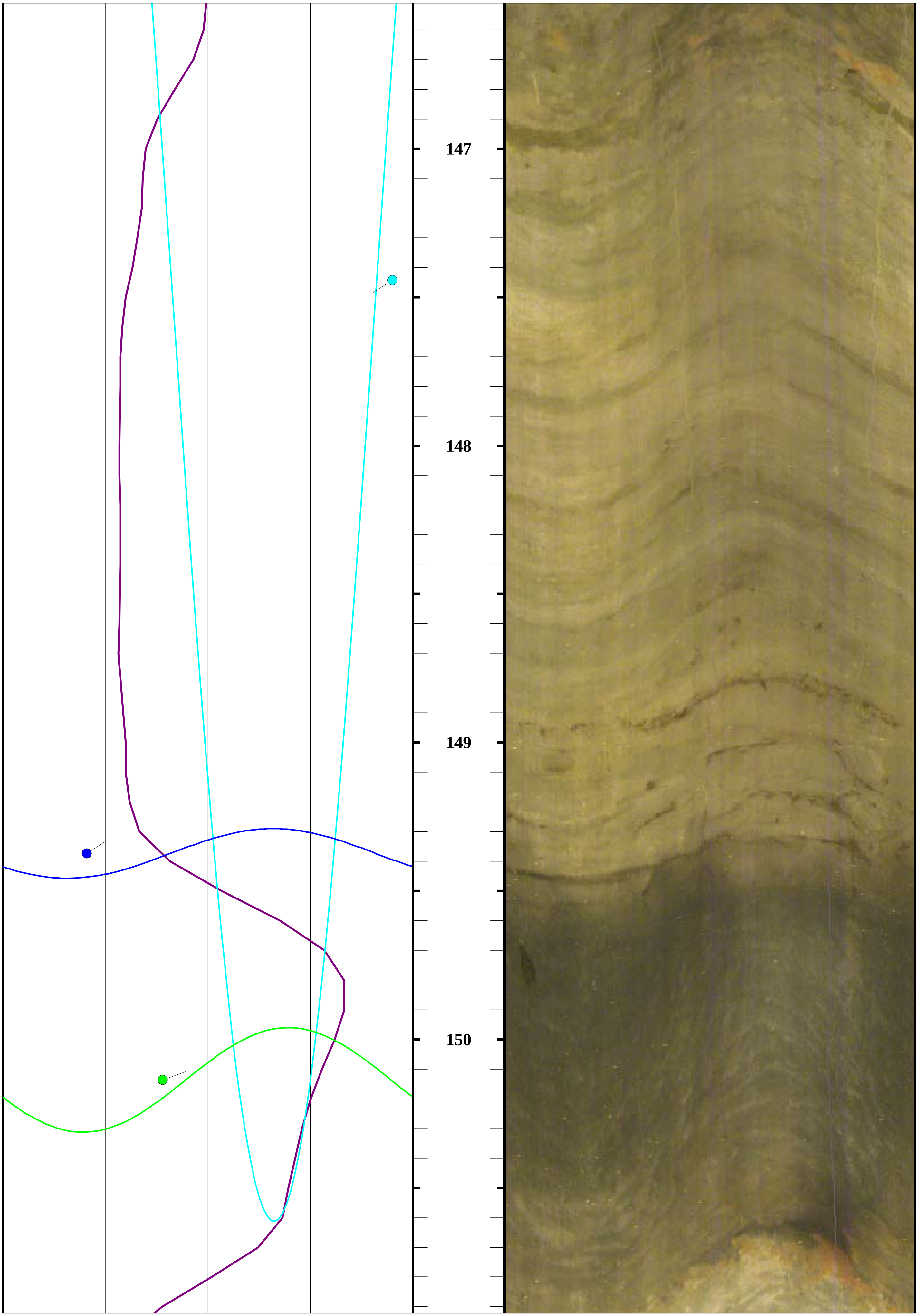

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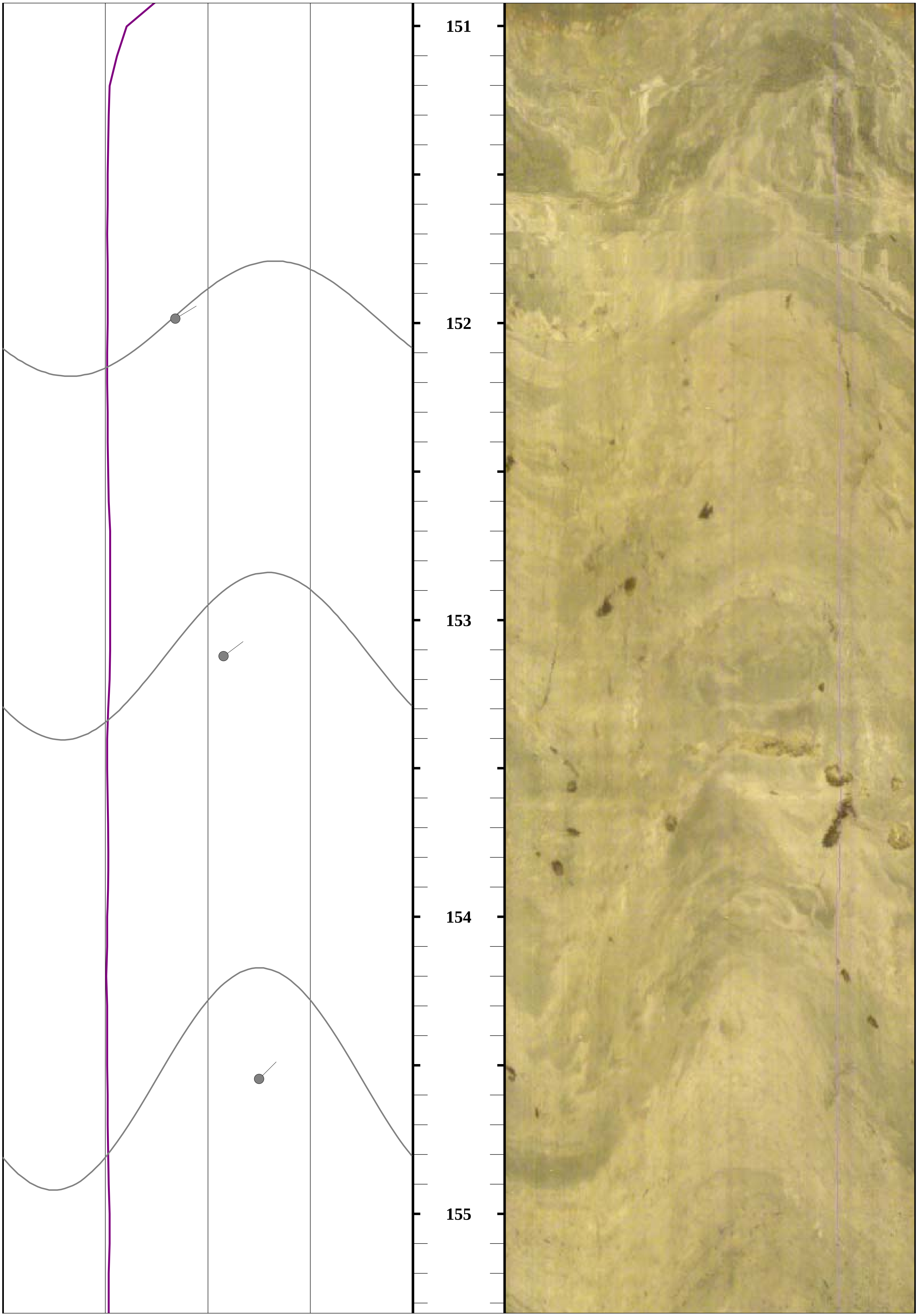
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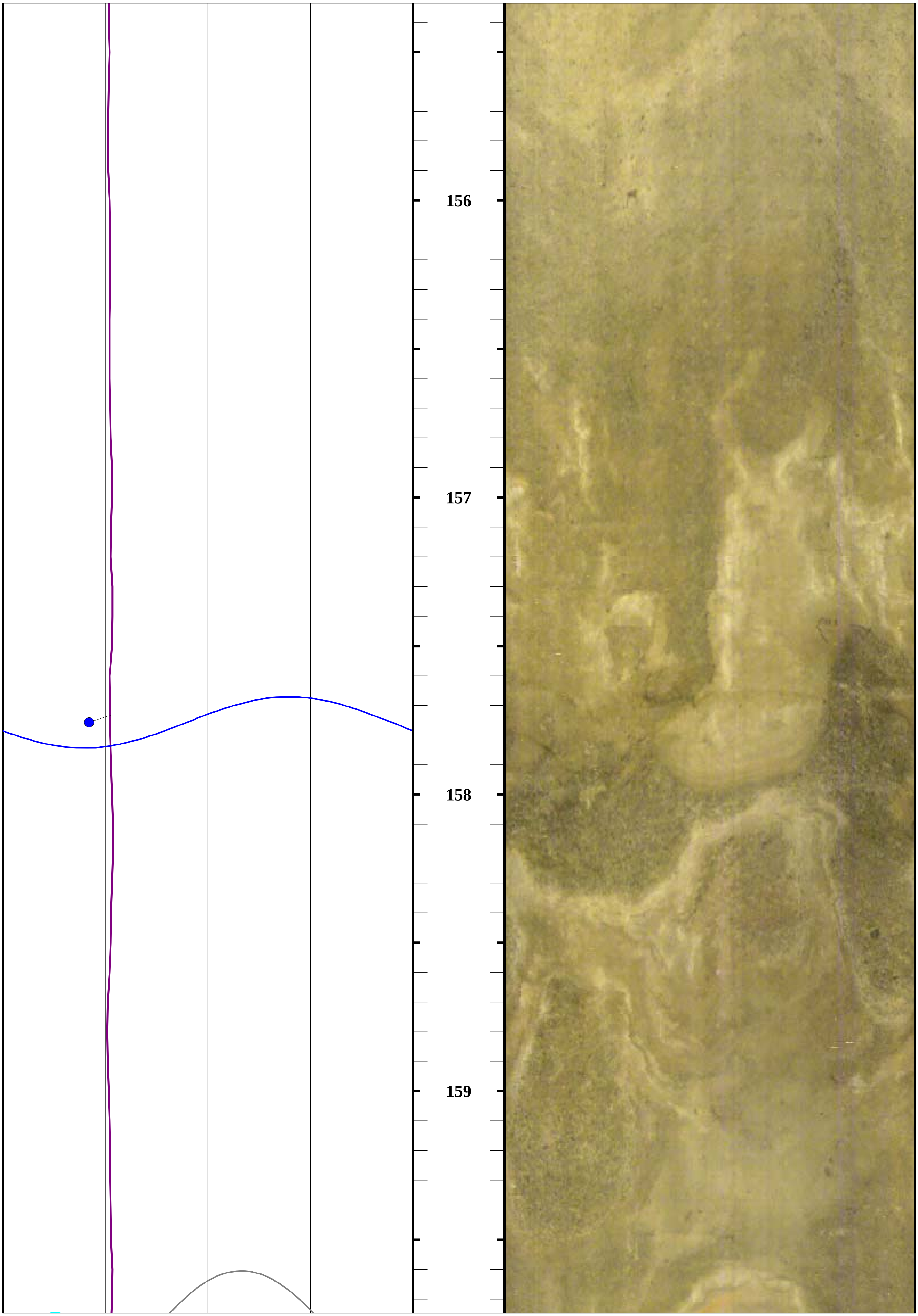
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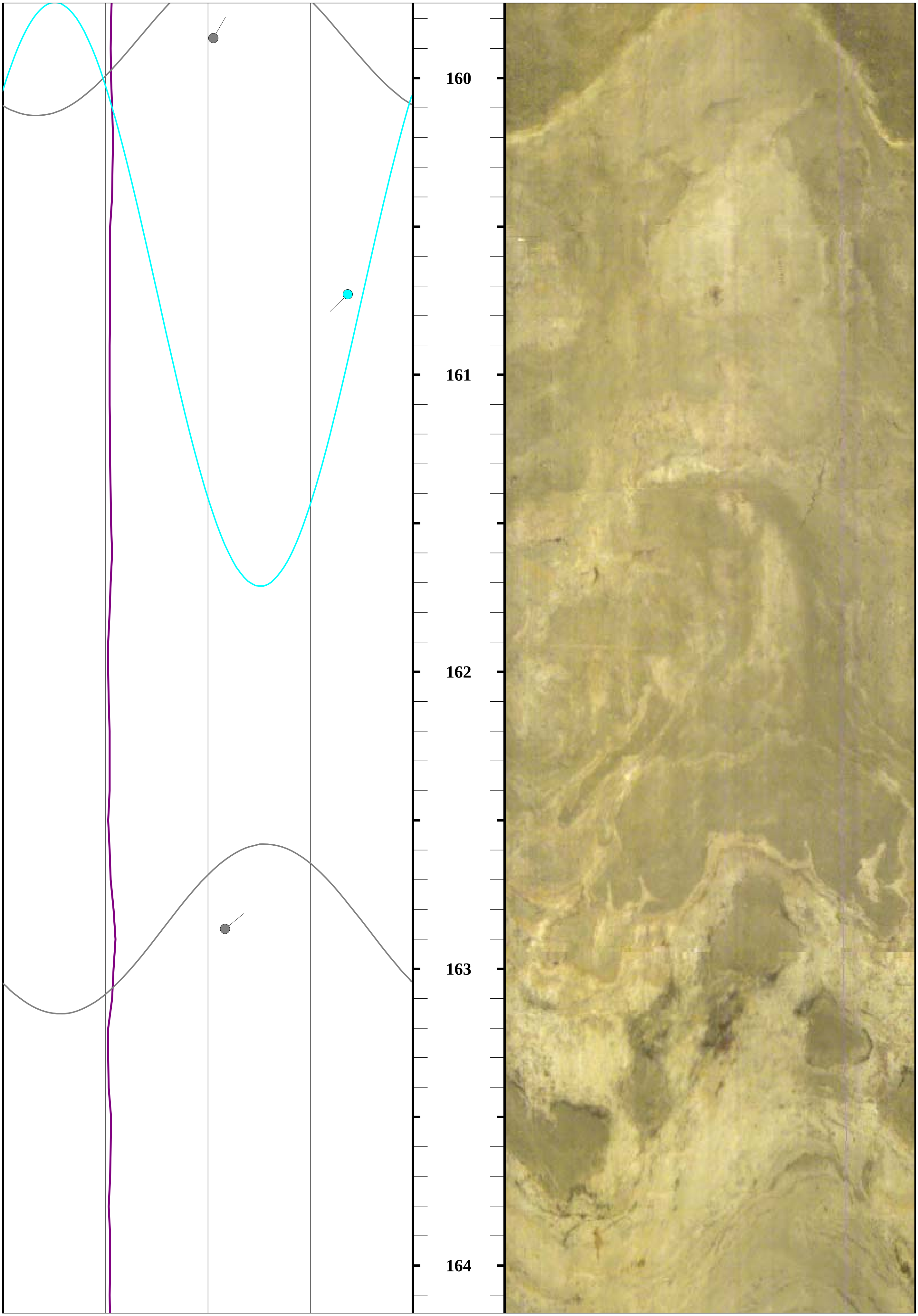
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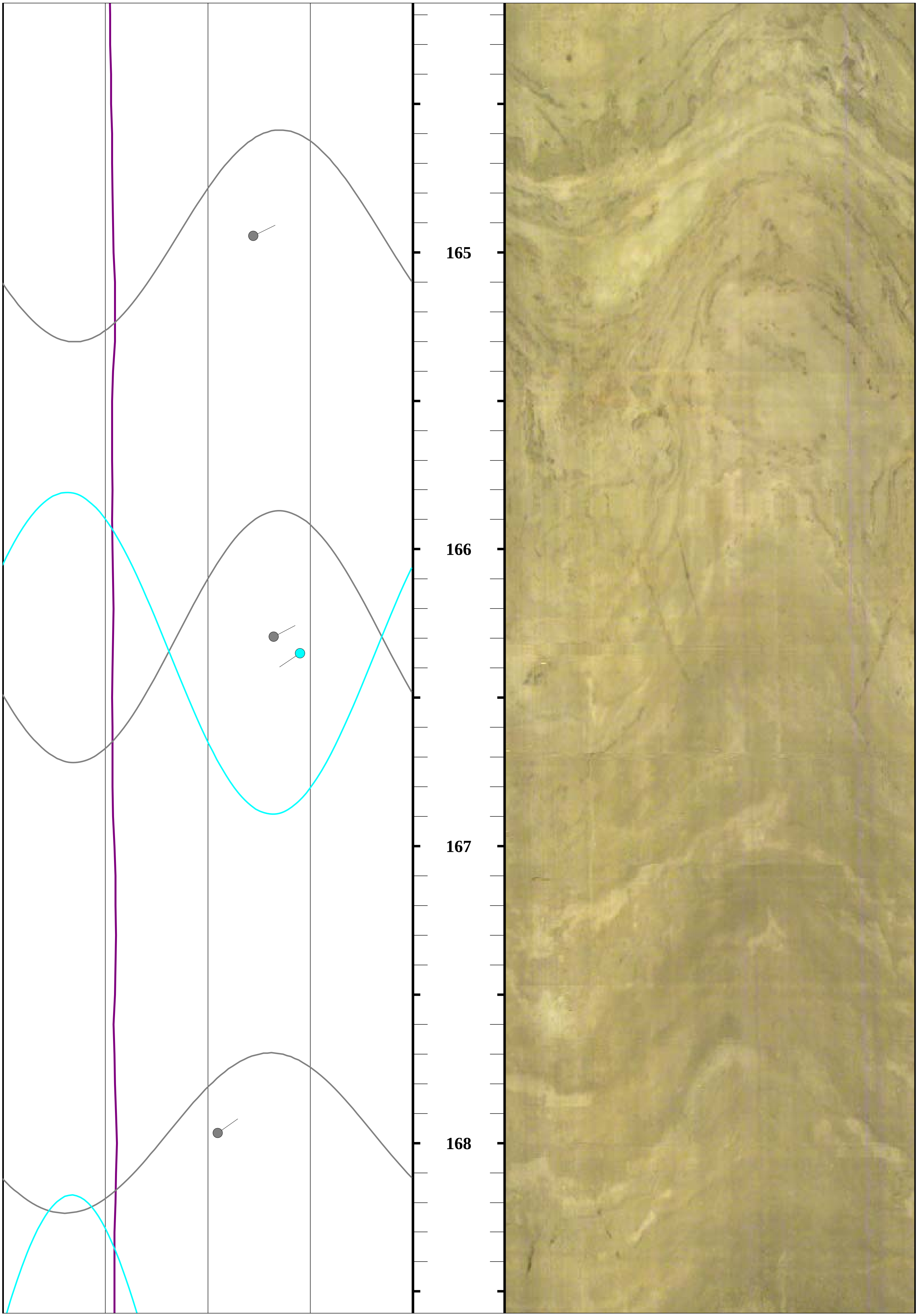
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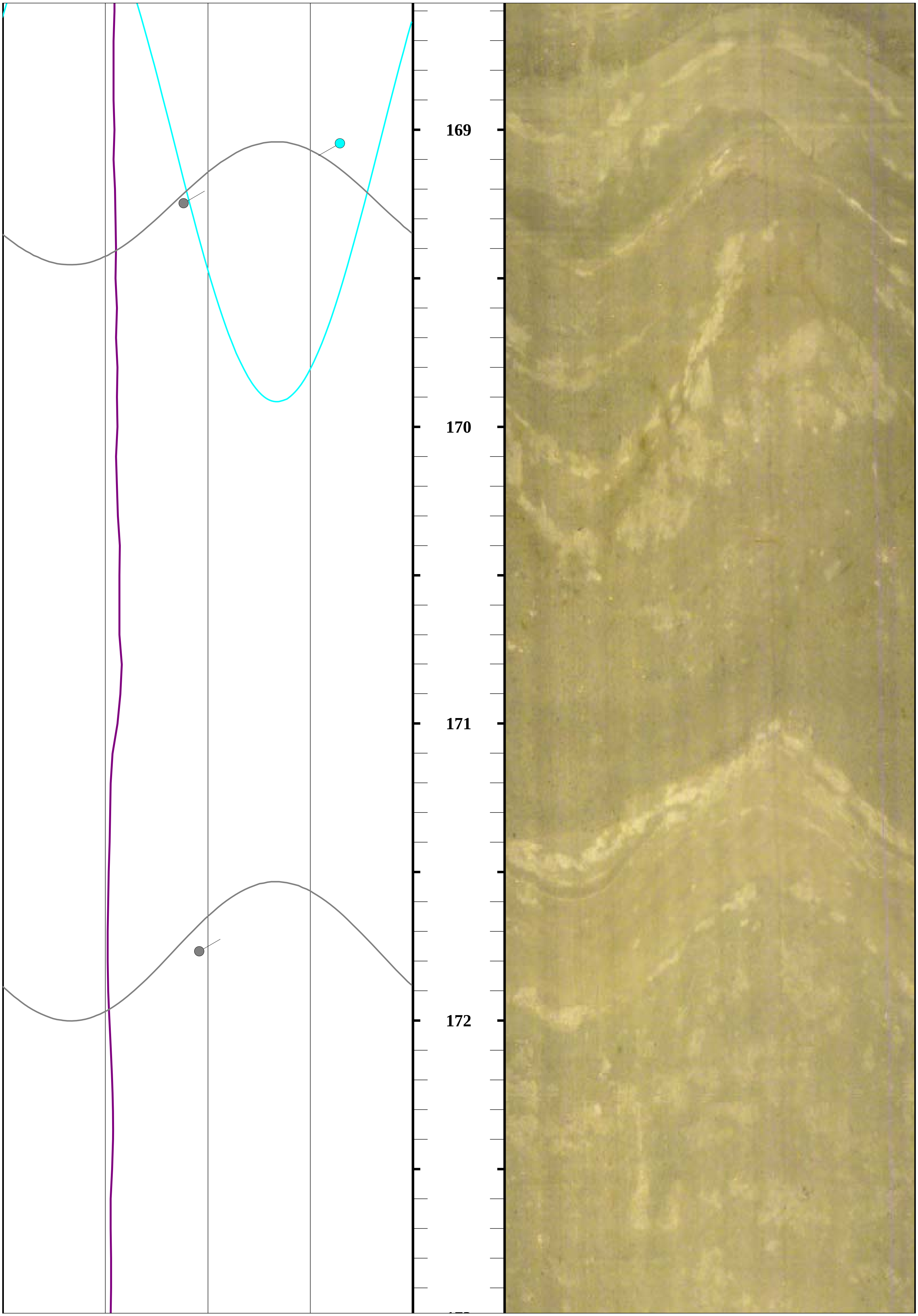
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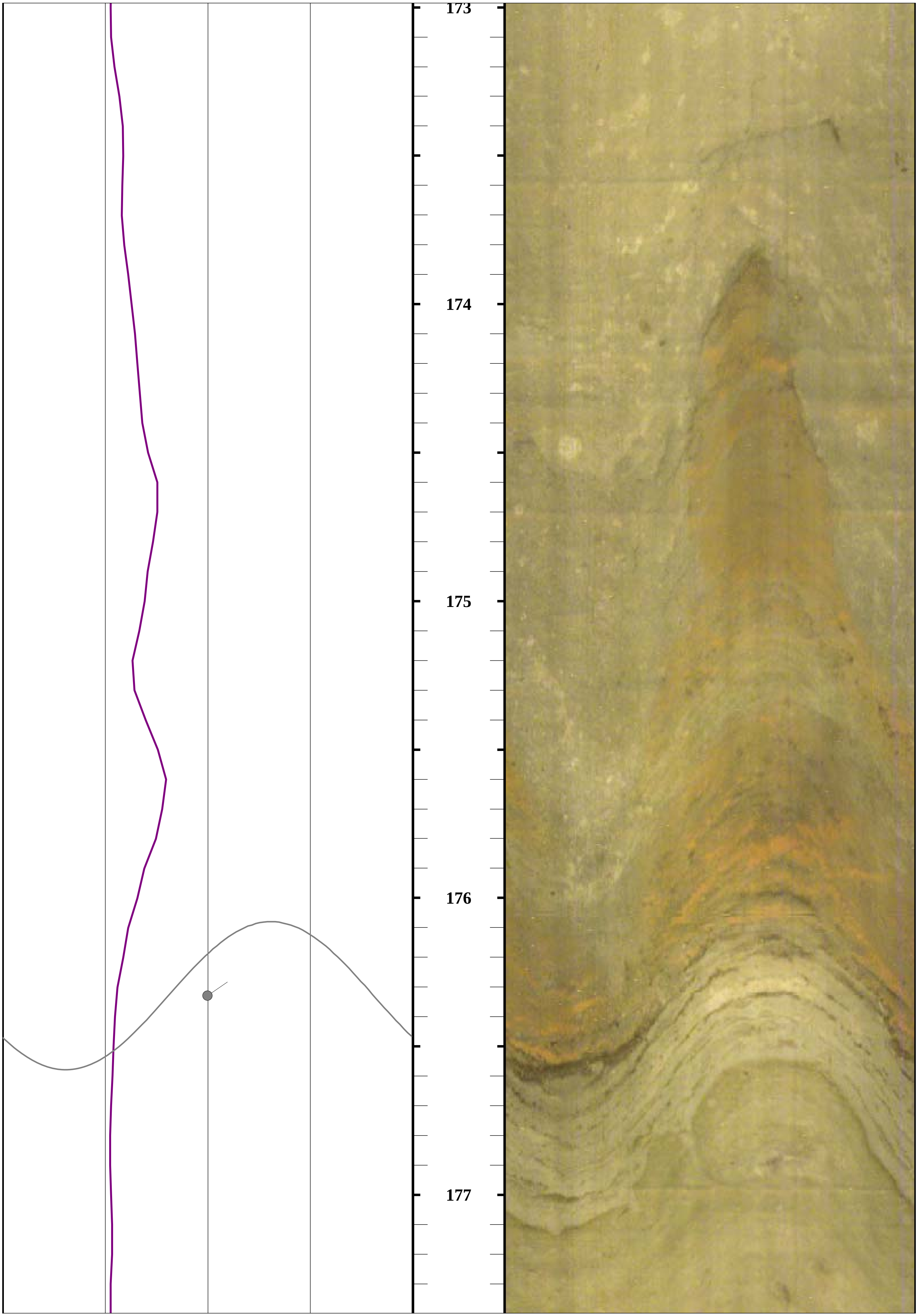

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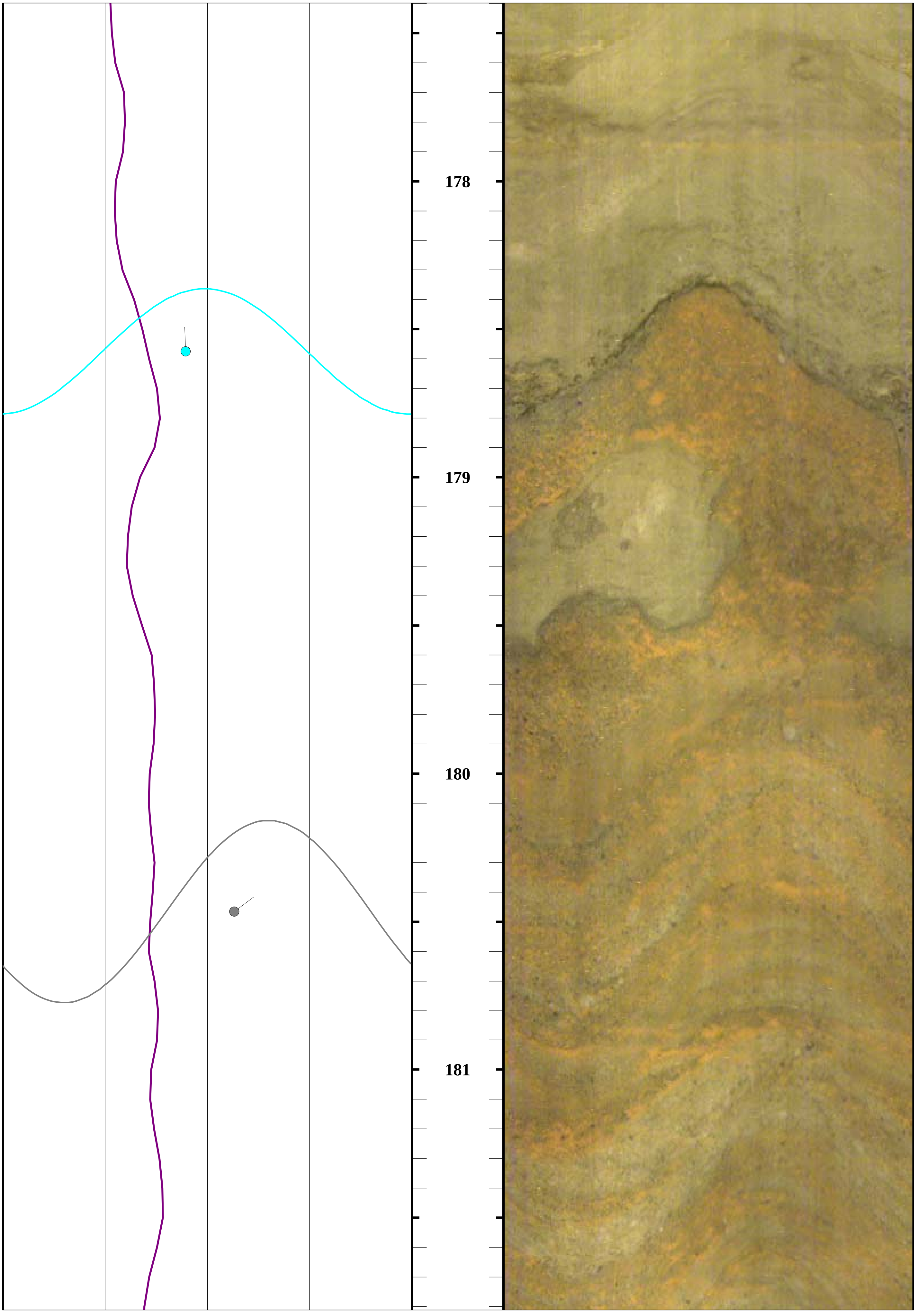
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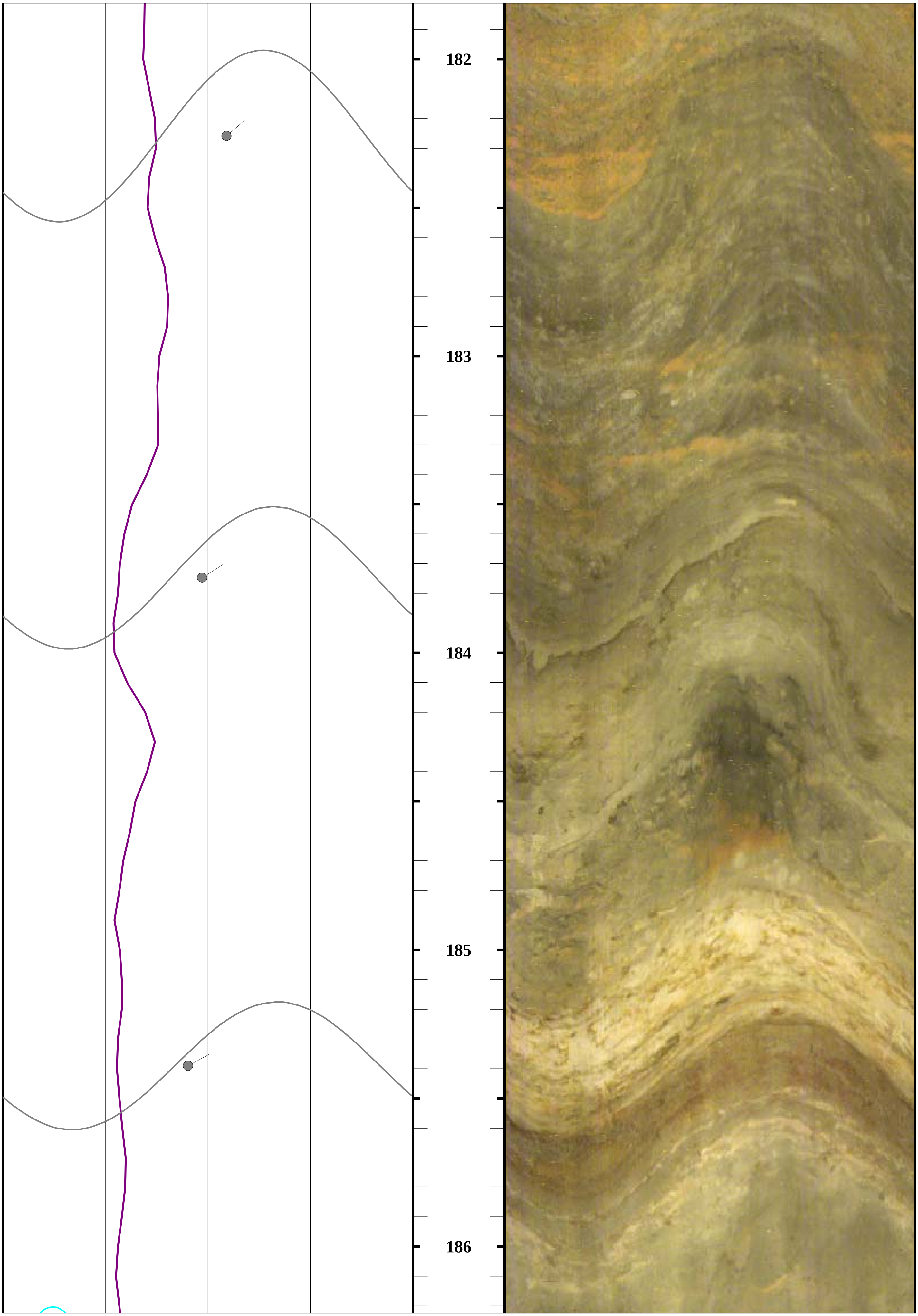
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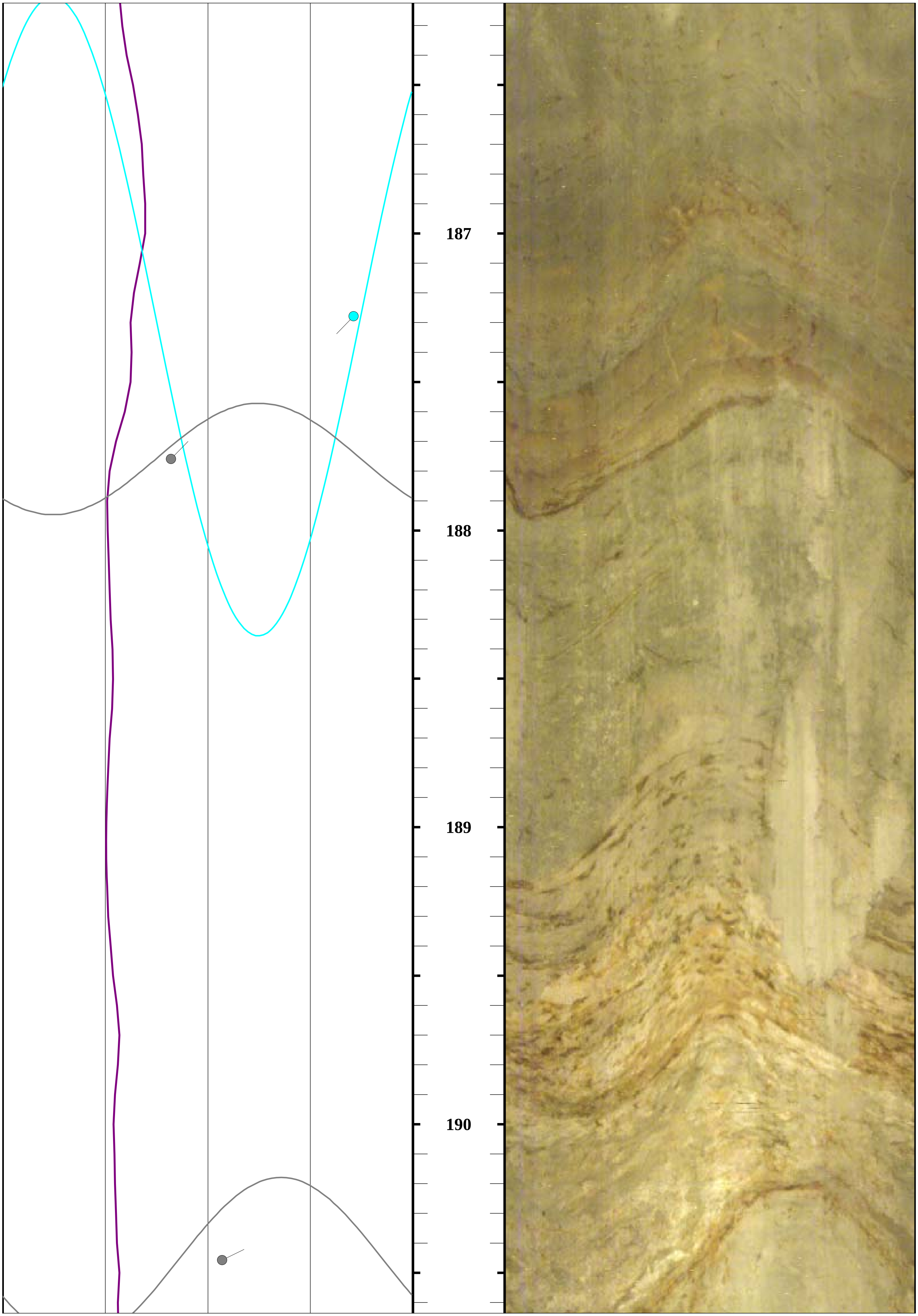
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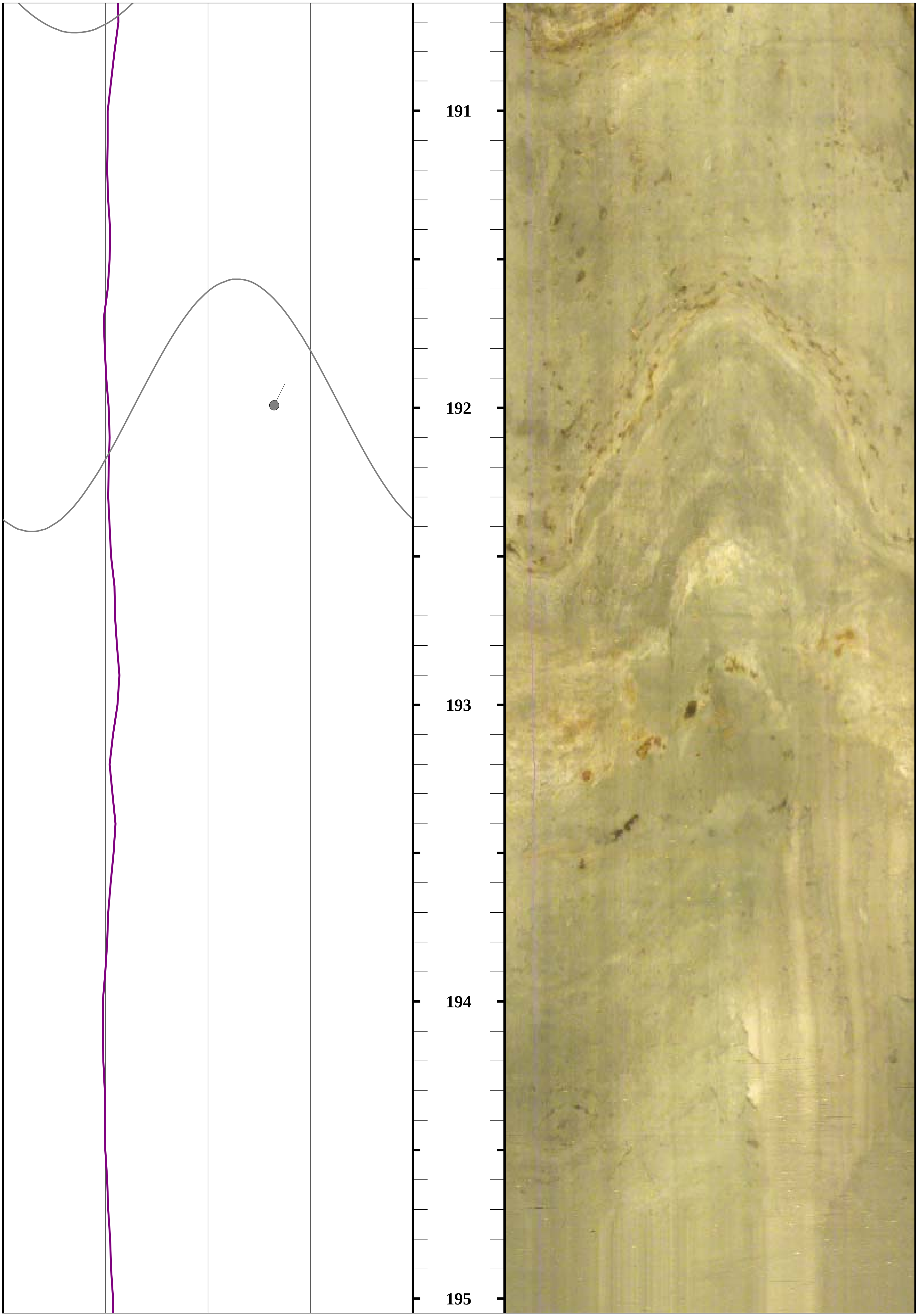
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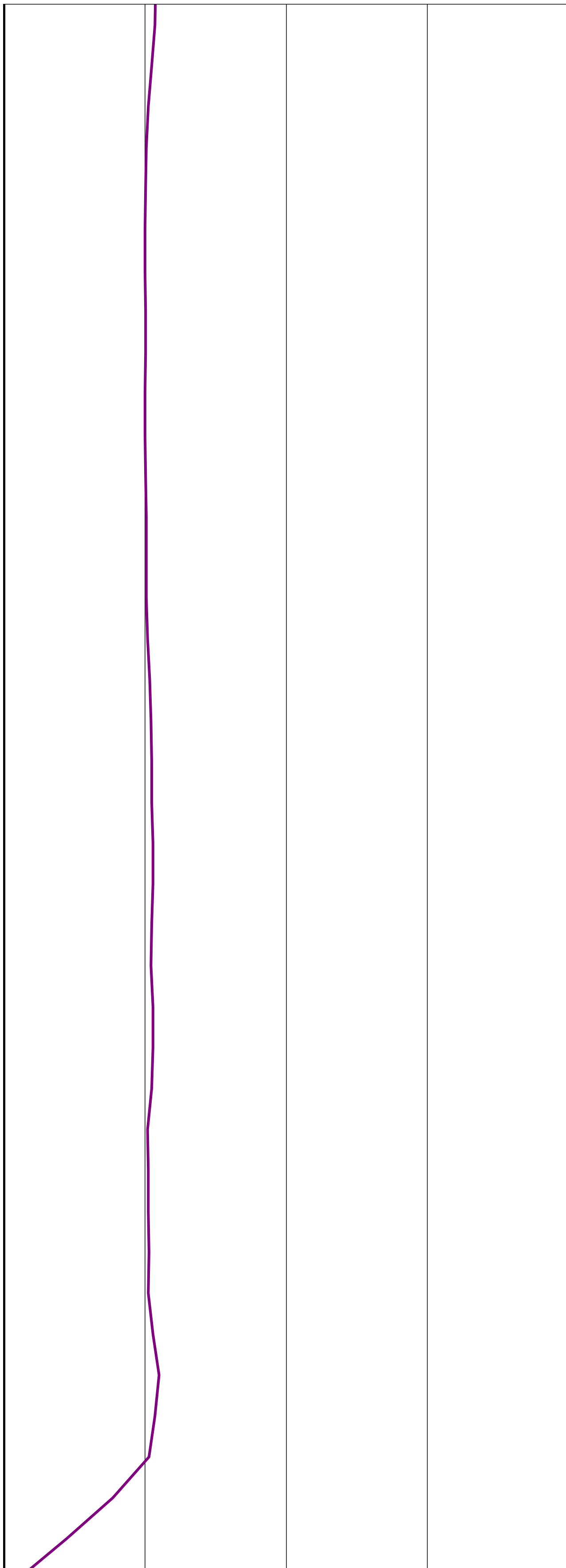

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Tadpoles - MN

0 90

Projections - MN

0° 90° 180° 270° 0°

3-Arm Caliper

5 in 9

Depth

1ft:5ft

Optical Image - MN

0° 90° 180° 270° 0°

Orientation Summary Table
Image Features
WSP
Project: Nu-West CPO
Well: A-16
8 September 2011

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	35.73	117.2	67	51	0
2	36.25	118.9	51	35	1
3	36.53	119.9	85	41	0
4	37.14	121.9	180	85	1
5	37.30	122.4	54	38	0
6	37.75	123.9	38	41	0
7	38.24	125.5	48	40	0
8	38.58	126.6	37	38	0
9	39.02	128.0	47	38	0
10	39.44	129.4	45	35	1
11	40.08	131.5	69	40	0
12	40.55	133.0	59	41	5
13	40.76	133.7	54	38	0
14	41.13	134.9	190	79	1
15	41.26	135.4	201	81	1
16	41.37	135.7	48	52	0
17	41.69	136.8	50	48	0
18	41.94	137.6	50	46	0
19	42.34	138.9	46	50	0
20	43.43	142.5	47	37	0
21	43.53	142.8	246	83	1
22	44.14	144.8	56	44	0
23	44.58	146.3	47	41	0
24	44.94	147.4	238	85	1
25	45.53	149.4	57	18	2
26	45.76	150.1	71	35	5
27	46.33	152.0	59	38	0
28	46.67	153.1	53	48	0
29	47.11	154.6	45	56	0
30	48.09	157.8	71	19	2
31	48.73	159.9	30	46	0
32	48.99	160.7	226	76	1
33	49.64	162.9	51	49	0
34	50.27	164.9	63	55	0
35	50.69	166.3	63	59	0
36	50.70	166.4	237	65	1
37	51.20	168.0	55	47	0
38	51.53	169.1	241	74	1
39	51.59	169.3	60	40	0
40	52.36	171.8	60	43	0
41	53.75	176.3	55	45	0
42	54.43	178.6	358	40	1
43	55.01	180.5	54	51	0
44	55.55	182.3	49	49	0
45	56.01	183.8	58	44	0

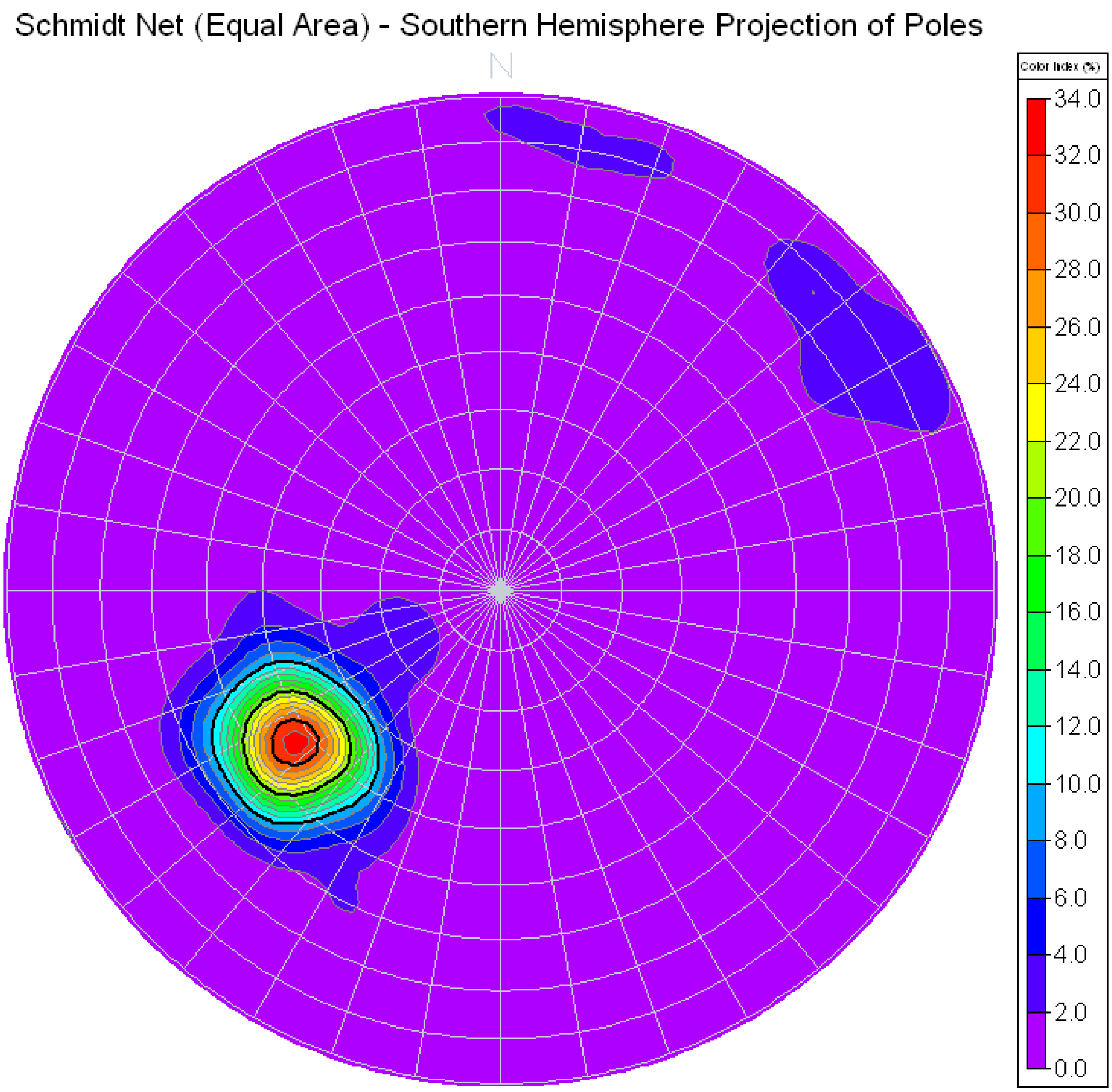
All directions are with respect to Magnetic North.

Orientation Summary Table
Image Features
WSP
Project: Nu-West CPO
Well: A-16
8 September 2011

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
46	56.51	185.4	61	41	0
47	57.08	187.3	224	77	1
48	57.23	187.8	44	37	0
49	58.05	190.5	64	48	0
50	58.52	192.0	26	60	0

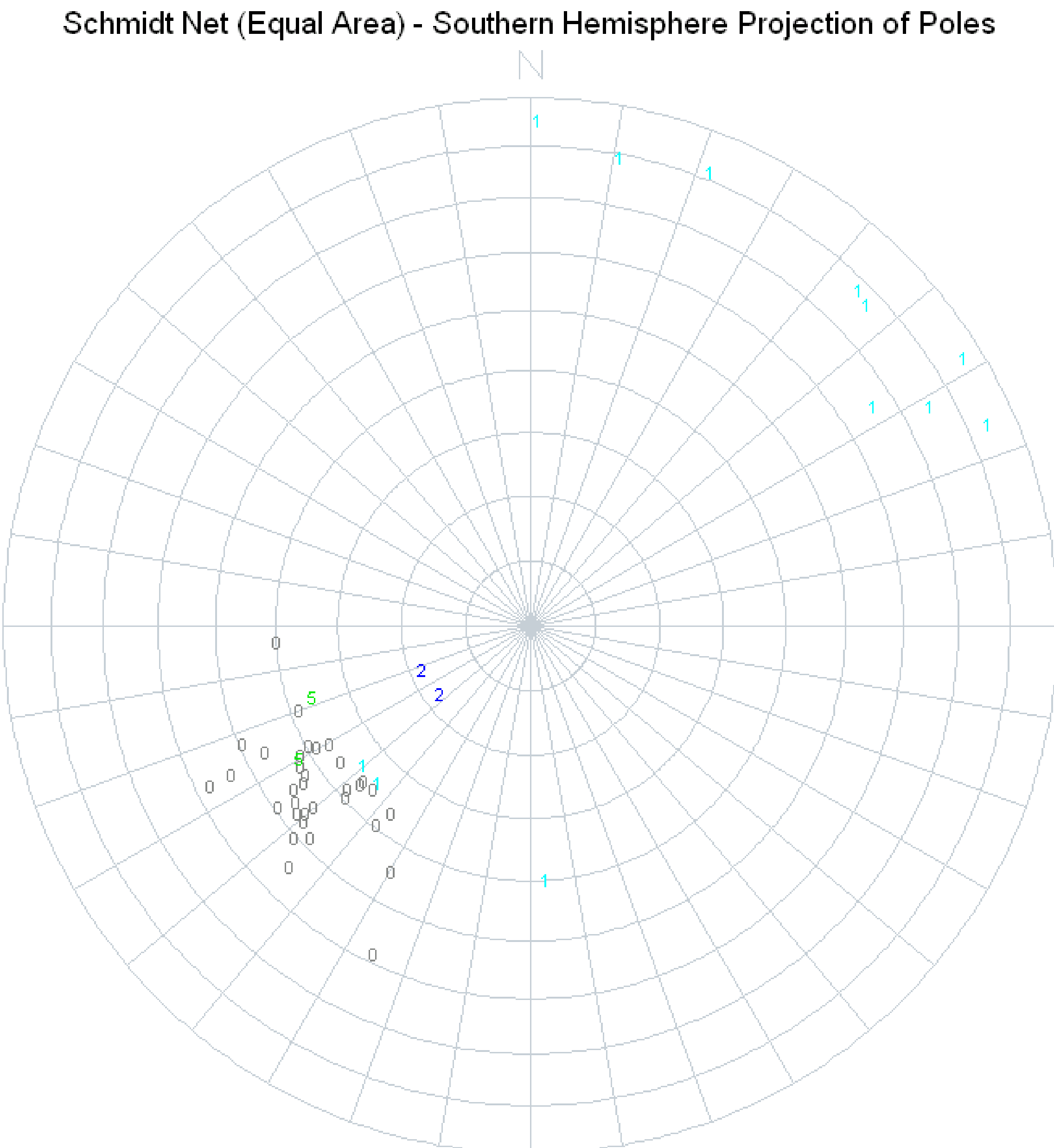
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Image Features
WSP
Project: Nu-West CPO
Well: A-16
8 September 2011



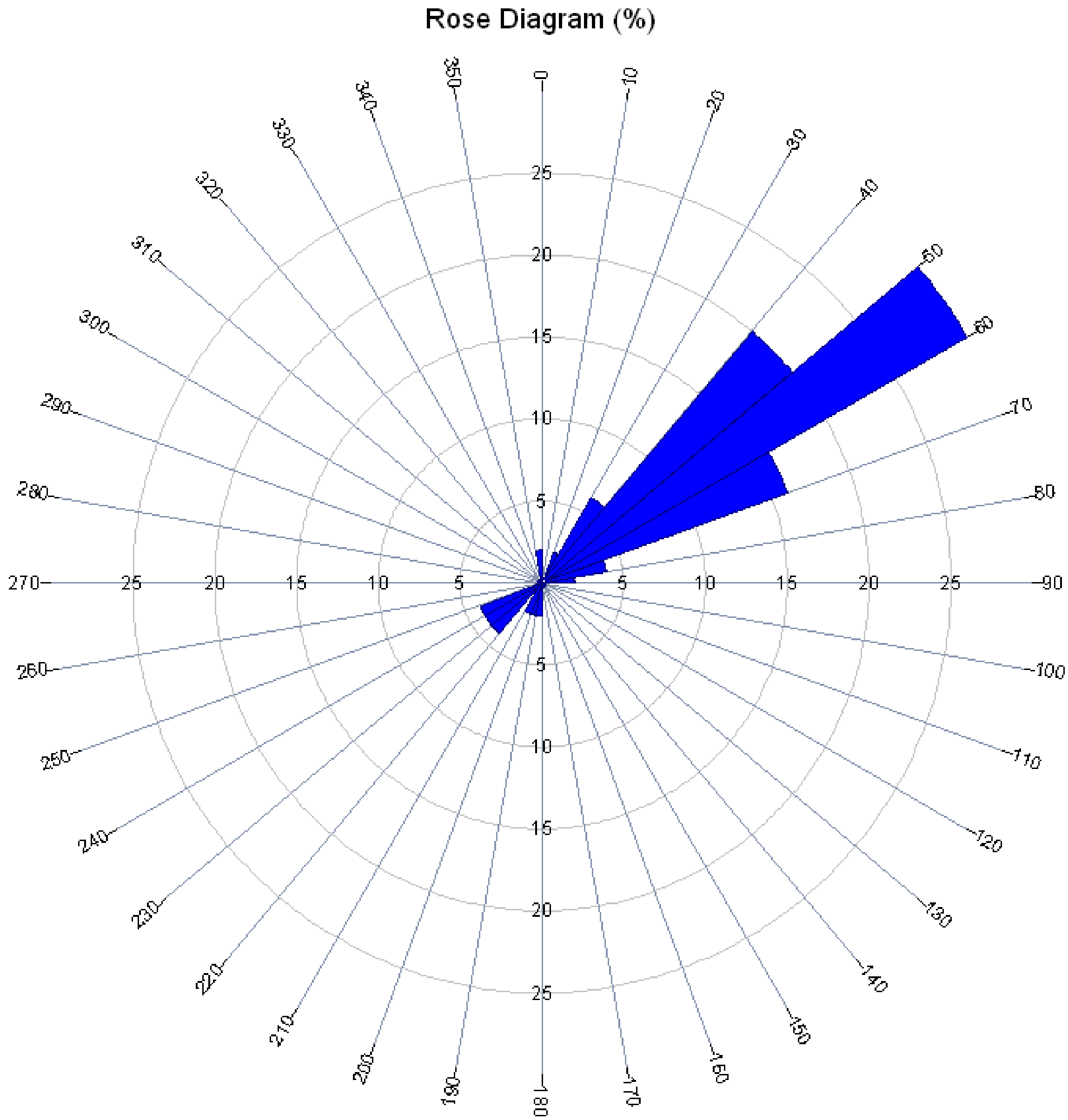
All directions are with respect to Magnetic North.

Stereonet Diagram – Schmidt Projection
Image Features
WSP
Project: Nu-West CPO
Well: A-16
8 September 2011



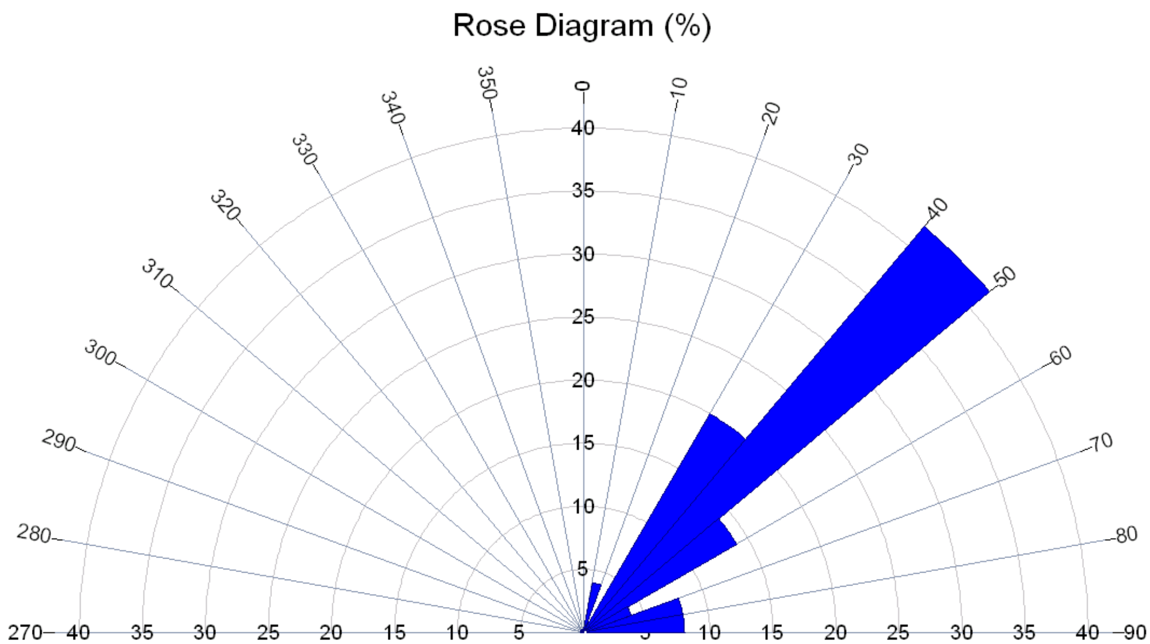
All directions are with respect to Magnetic North.

Rose Diagram – Dip Directions
Image Features
WSP
Project: Nu-West CPO
Well: A-16
8 September 2011



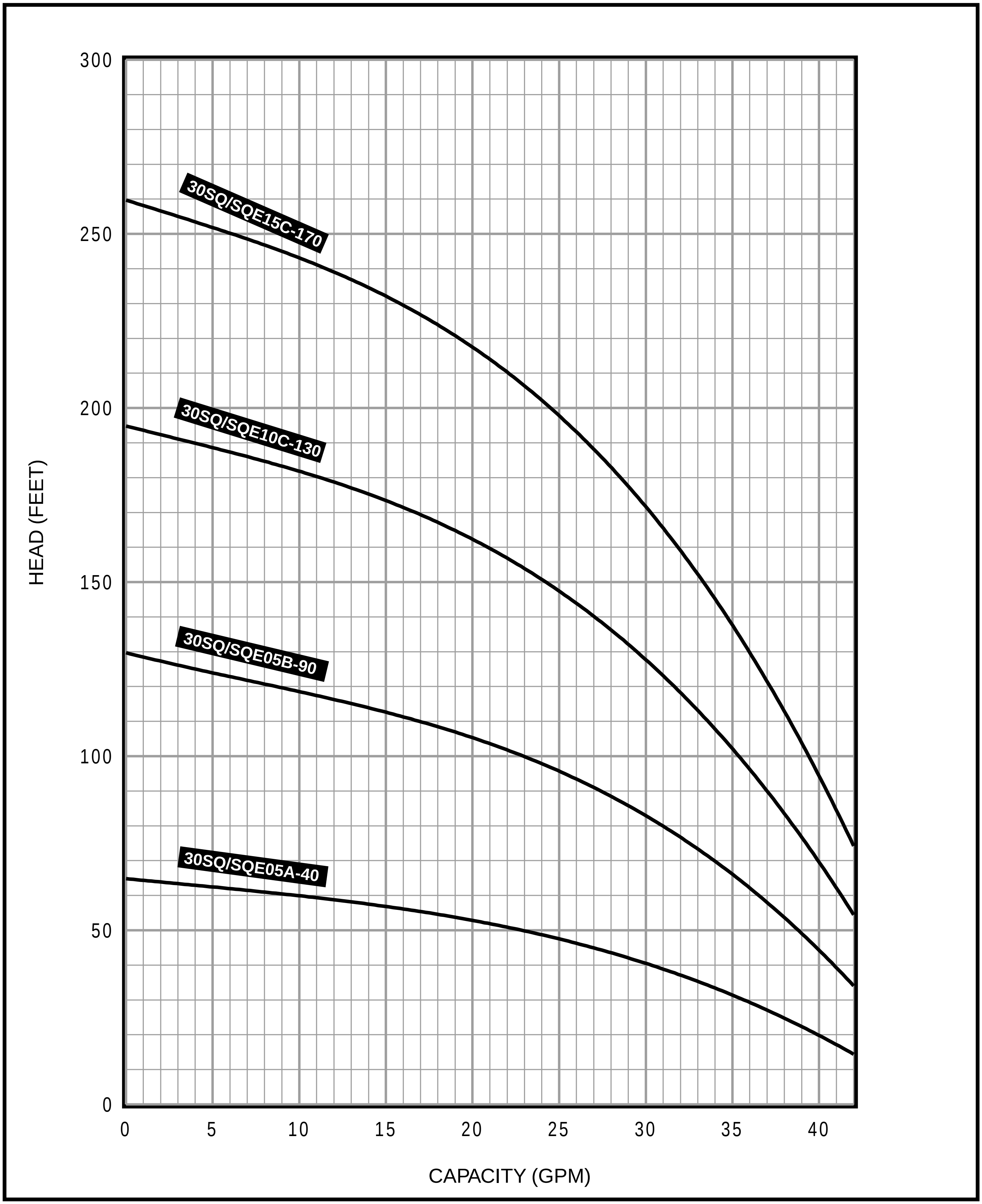
All directions are with respect to Magnetic North.

Rose Diagram – Dip Angles
Image Features
WSP
Project: Nu-West CPO
Well: A-16
8 September 2011



All directions are with respect to Magnetic North.

FLOW RANGE: 8 - 42 GPM **OUTLET SIZE: 1 1/2" NPT** **NOMINAL DIA. 3"**



SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE. PERFORMANCE CONFORMS TO ISO 2548 ANNEX B.

DIMENSIONS AND WEIGHTS

MODEL NO.	FIG.	HP	MOTOR SIZE	DISCH. SIZE	DIMENSIONS IN INCHES					APPROX. SHIP WT.
					A	B	C	D	E	
30SQ/SQE05A-40	A	1/2 A	3"	1 1/2" NPT	30.4	19.8	10.6	2.6	2.9	12
30SQ/SQE05B-90	A	1/2 B	3"	1 1/2" NPT	30.4	19.8	10.6	2.6	2.9	13
30SQ/SQE10C-130	A	1 C	3"	1 1/2" NPT	35.0	21.3	13.7	2.6	2.9	13
30SQ/SQE15C-170	A	1 1/2 C	3"	1 1/2" NPT	35.0	21.3	13.7	2.6	2.9	16

NOTES: All models suitable for use in 3" wells, unless otherwise noted.
Weights include pump end with motor in lbs.

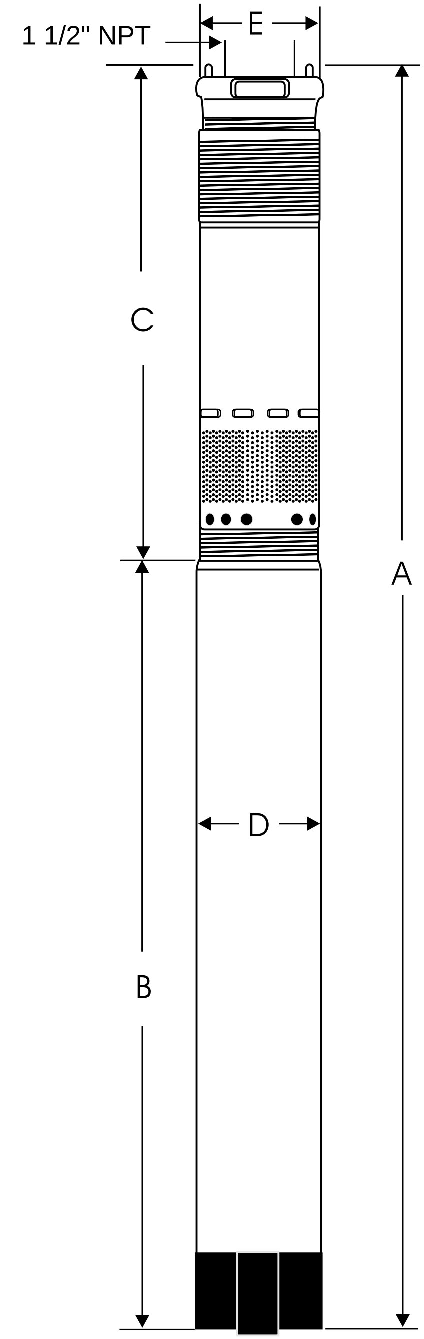


Fig. A

MATERIALS OF CONSTRUCTION

COMPONENT	SPLINED SHAFT
Valve Casing	Polyamide
Discharge Chamber	304 Stainless Steel
Valve Guide	Polyamide
Valve Spring	316LN Stainless Steel
Valve Cone	Polyamide
Valve Seat	NBR Rubber
O-ring	NBR Rubber
Lock ring	310 Stainless Steel
Top Bearing	NBR Rubber
Top Chamber	Polyamide
Guide Vanes	Polyamide
Impeller	Polyamide w/tungsten carbide bearings
Bottom Chamber	Polyamide
Neck Ring	Polyamide
Bearing	Ceramic
Suction Interconnector	Polyamide
Ring	304 Stainless Steel
Pump Sleeve	304 Stainless Steel
Cone for pressure equalization	Polyamide
Spacer	Polyamide
Sand Trap	316 Stainless Steel
Shaft w/coupling	304 Stainless Steel
Cable Guard	304 Stainless Steel

NOTES: Specifications subject to change without notice.